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Technical Impracticability Evaluation for Groundwater Restoration

**Former Somers Tie Treating Plant
Somers, Montana**

Prepared by:

The RETEC Group, Inc.
1726 Cole Boulevard, Building 22, Suite 150
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RETEC Project Number: BN080-01860-240

Prepared for:

The Burlington Northern and Santa Fe Railway Company
139 North Last Chance Gulch
Helena, Montana 59601

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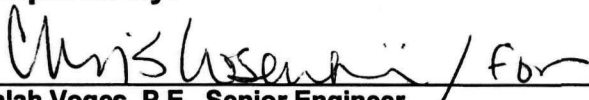
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Executive Summary

This document presents a technical impracticability (TI) evaluation for restoration of groundwater at The Burlington Northern and Santa Fe Railway Company (BNSF) Somers former Tie Treating Plant in Somers, Montana. CERCLA (42 U.S.C. 9621(d)(4)) and EPA guidance on TI evaluations (EPA, 1993) recognize that restoration of contaminated groundwater to drinking water quality may not be possible due to technical limitations at some sites. The TI evaluation presented in this document is made following 6 years of groundwater remedy implementation. This evaluation shows that, it is technically impracticable to restore groundwater to the Ambient Water Quality Criteria and MCLs specified in the 1989 Record of Decision and subsequent modifications (collectively the "ROD") due to characteristics of the site geology and hydrogeology and due to the nature of the creosote contamination present in the subsurface.

BNSF is requesting a waiver of applicable or relevant and appropriate requirements (ARARs) for groundwater, based on the technical impracticability of restoring the surficial aquifer to drinking water quality. The waiver would apply to areas of the surficial aquifer that contain residual creosote contaminated soil, which are a source to groundwater, as well as areas where groundwater exceeds ARARs in the ROD. BNSF is not requesting a waiver of risk-based levels in the ROD. The selected remedy includes institutional controls on impacted property and designation of a Controlled Groundwater Use Area of the surficial aquifer in the impacted areas. These institutional controls eliminate the exposure pathway to impacted groundwater. As a result, the remedy will be protective even if groundwater ARARs are waived.

BNSF is requesting a waiver, to be implemented through an Explanation of Significant Differences (ESD) issued by EPA, of the following ARARs set forth in the ROD:

- Primary MCL: Benzene 5 ug/L
- Secondary MCL: Zinc 5000 ug/L
- Ambient Water Quality Criteria:
 - Acenaphthene 20 ug/L
 - Fluoranthene 42 ug/L
 - Naphthalene 620 ug/L
 - Total CPAH 0.030 ug/L
 - Phenol 3500 ug/L/2500 ug/L
 - Zinc 110 ug/L

Source removal was conducted prior to the issuance of the ROD in 1989. In 1985, BNSF implemented an emergency removal action in the swamp pond area under an Administrative Order for Immediate Removal with EPA. Approximately 3,000 cubic yards of the most heavily contaminated soil and over 100,000 gallons of

Executive Summary

contaminated water from the swamp pond area and a portion of the drainage ditch were removed. In 1988, BNSF conducted a removal action of beach sediments along the site bordering Flathead Lake. Approximately 40 cubic yards of contaminated sediment was removed and placed in the CERCLA lagoon (RETEC, 1989).

Three remedial investigations conducted at the Somers site found that groundwater within the CERCLA lagoon and a portion of the swamp pond contained creosote oil. Creosote oil is a dense, nonaqueous-phase liquid (DNAPL).

The ROD specified two primary components of the remedy for the Somers site: a soil remedy and a groundwater remedy. The soil remedy required excavation of approximately 53,500 cubic yards of contaminated soil and sediment and treatment in an on-site Land Treatment Unit. The groundwater remedial action specified by the ROD was installation of a pump and treat system to remove available free-phase creosote contamination from the surficial aquifer in the CERCLA lagoon and swamp pond areas (EPA, 1989). The second aspect of this remedial action was to conduct *in-situ* biological treatment to degrade both contaminants adsorbed onto the aquifer matrix and residual contaminants dissolved in the groundwater (EPA, 1989).

The evaluation of the groundwater treatment system performance is presented in Section 3. The evaluation indicates that full aquifer restoration (as defined in the ROD), cannot be achieved within a reasonable timeframe. Following six years of system operation, two percent of the DNAPL contamination estimated to remain in the subsurface has been removed. Additionally, groundwater quality immediately adjacent to the treatment area has not improved. These data indicate that the selected groundwater remedy cannot restore the surficial aquifer at the Somers site to drinking water quality in less than 1,700 years. The primary impediment to restoration of the aquifer is the inability to extract contaminants or circulate nutrient-enriched water effectively.

Potential groundwater remedial alternatives to restore groundwater to drinking water quality are discussed in Section 4 of this TI evaluation. None of those alternatives are able to restore the surficial aquifer within a reasonable time frame.

This TI evaluation demonstrates that available groundwater treatment technologies cannot restore the surficial aquifer to drinking water quality within a reasonable time frame. BNSF proposes that EPA waive ARARs and determine that protection of human health and the environment has been achieved through a combination of source removal and institutional controls (such as the designation of a Controlled Groundwater Use Area).

1 Introduction

This document presents a technical impracticability (TI) evaluation for restoration of groundwater at the BNSF Somers former Tie Treating Plant in Somers, Montana (Figure 1-1), hereafter referred to as the Somers Site. Under CERCLA Section 121(d)(4)(C), the United States Environmental Protection Agency (EPA) may select a remedial action that does not attain "legally applicable or relevant and appropriate requirements" (ARARs) if "compliance with such requirements is technically impracticable from an engineering perspective." EPA's guidance on TI evaluations (EPA, 1993) recognizes that restoration of contaminated groundwater to meet ARARs (such as maximum containment levels [MCLs]) may not be possible due to technical limitations at some sites. The TI evaluation presented in this document is made following 6 years of groundwater remedy implementation. This evaluation will show that, due to characteristics of the site geology, hydrogeology, and the creosote contamination present in the subsurface, restoration of groundwater to meet the ARARs specified in the 1989 Record of Decision (ROD) is technically impracticable. Protectiveness of human health is expected to be achieved through the designation of a Controlled Groundwater Use Area to prevent the installation of groundwater supply wells, thereby eliminating the groundwater exposure pathway.

This introductory section summarizes the requirements of the ROD, discusses the TI process outlined by EPA, and concludes with a guide to subsequent sections of this report.

1.1 ROD Requirements

This section discusses the criteria that must be met by remedies under CERCLA, and then discusses those remedies specified for the Somers site in the ROD and the ARARs and risk-based remediation concentrations specified in the ROD.

1.1.1 CERCLA Remedy Selection Criteria

Under CERCLA, all remedies are required to be protective of human health and the environment, and to attain the ARARs associated with the selected remedy. All remedies selected for a site must meet these "threshold" criteria. All remedies should also be cost-effective, use permanent solutions to the extent practicable, and use alternative or innovative treatment technologies to the extent possible. In addition, a primary component of the remedy must be a reduction in contaminant toxicity, mobility, or volume.

Selection of various potential remedial alternatives are made in accordance with the following nine criteria:

- Overall protection of human health and the environment
- Compliance with ARARs
- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume
- Short-term effectiveness
- Implementability
- Cost
- State acceptance
- Community acceptance

Each alternative is evaluated against the above criteria to determine its relative strengths and weaknesses. Consideration is then given to the suitability of each alternative for the site based on this evaluation. The final, selected option is that which best satisfies all criteria for the site and the media (e.g., soil or groundwater) being remediated. Under some circumstances, ARARs may be waived by EPA, however the requirement to protect human health and the environment cannot be waived. The next section discusses the remedial actions selected for the Somers site using the criteria discussed above.

1.1.2 Summary of the Record of Decision

The 1989 ROD and subsequent Explanations of Significant Differences (EPA, 1992 and 1998) documented the soil and groundwater remedy and both numeric, ARAR-based and risk-based cleanup criteria for the Somers site. The ROD discussed effected soil and groundwater, creosote toxicity and the current and/or potential environmental exposure routes. These documents specified two primary components of the remedy for the Somers site: a soil remedy, requiring excavation and on-site land treatment; and a groundwater remedy consisting of extraction, treatment and reinjection of oxygen and nutrient enriched water into the aquifer to enhance in situ biological treatment.

1.2 Technical Impracticability Process

EPA's experience with groundwater remediation has shown that restoration of aquifers to meet ARARs, such as drinking water MCLs, may not always be

achievable due to the limitations of available technologies combined with the geological and chemical complexities of many hazardous waste sites (EPA, 1993). The TI guidance outlines EPA's approach to evaluating the TI of restoring groundwater to meet ARARs, and recommends objectives and options for alternative, remedial strategies for a site that are protective even if restoration to meet ARARs is judged to be technically impracticable (EPA, 1995). This guidance does not represent a reduction in EPA's efforts to restore contaminated groundwater. Rather, the guidance recognizes that restoration of contaminated groundwater to meet ARARs may not be possible due to technical limitations at some sites. As stated in OSWER Directive 9200.4-14, "the goal of ground-water cleanup at Superfund sites continues to be restoration of contaminated ground water to ARAR-based cleanup levels wherever technically practicable."

In particular, EPA cites the presence of non-recoverable dense nonaqueous-phase liquids (DNAPLs) to be one of the primary factors preventing complete restoration of contaminated groundwater sites. EPA also notes that "DNAPL sites are more likely to require TI evaluations than sites with other types of contamination" (EPA, 1993).

Under EPA guidance, a "technical impracticability decision may be made as soon as sufficient information is available to demonstrate that such a finding is appropriate." The TI decision can be made at the time of the ROD based upon investigation or pilot study data, or after the ROD following an evaluation of the implemented site remedy. In the case of Somers this evaluation is being made following implementation of the soil remedy and six years of groundwater remedy operations.

The primary considerations for determining the TI of achieving ARARs are engineering feasibility and remedy reliability (EPA, 1993). Engineering feasibility may be defined as the technical and administrative ability to construct and operate a remedy that will achieve ARARs. The reliability of a remedy is based on its effectiveness, over the long-term, to protect human health and the environment even if ARARs are not achieved.

1.2.1 Applicability of a TI Waiver for the Somers Site

Approximately six years of groundwater remediation at the Somers site indicates that the selected groundwater remedy will not achieve the ARARs specified in Table 1-1 (i.e., the MCLs and ambient water quality criteria specified in Table 1 of the ROD). This is not surprising given the types of contaminants, the low permeability soils and complex hydrogeological conditions found at the site. In fact, EPA's TI guidance (1993) highlights those circumstances, which make remediation problematic. These include:

1. **Presence of DNAPL Contamination.** The term "dense nonaqueous-phase liquids" (DNAPLs) refers to liquids that are more dense than water and do not readily mix in water. They can sink in an aquifer, pool or pond at changes in lithological or stratigraphic boundaries and flow into pores and fractures. DNAPLs will serve as an ongoing source of aqueous dissolved contaminant concentrations. Technologies have not been developed which are 100 percent effective at removing DNAPL from aquifers.
2. **Complex Hydrogeology.** The more geologically complex an aquifer is, the more difficult DNAPL recovery and contaminant removal will be. Very low permeability soils, preferential pathways and other conditions can dramatically inhibit remediation technology feasibility.

The geology and hydrogeology at the Somers site represents a very complex system for remediation. DNAPL comprised of creosote and other compounds has migrated into the surficial aquifer and become trapped in thin, discontinuous sand lenses and small fractures in the otherwise low-permeability clayey, sandy, silty soils. As a result, there are numerous discrete and unconnected observations of creosote staining and residual droplets of DNAPL (and therefore very difficult to recover) in the surficial aquifer, acting as individual sources of dissolved contamination. Section 2 of this report presents a detailed summary of the site geology, hydrogeology, and contaminant characteristics, illustrating the challenges inherent in achieving remediation goals.

Table 1-1 Groundwater ARARs From 1989 ROD

Compound	1989 ROD Human Health (µg/L)	1989 ROD Aquatic Life (µg/L)
Acenaphthene	20 ⁽¹⁾	
Fluoranthene	42 ⁽¹⁾	
Naphthalene		620 ⁽¹⁾
Benzene	5 ⁽²⁾	
Total CPAH	0.030 ⁽¹⁾	
Phenol	3,500 ⁽¹⁾	2,500 ⁽¹⁾
Zinc	5,000 ⁽³⁾	110 ⁽¹⁾

(1) Clean Water Act Water Quality Criterion

(2) Safe Drinking Water Act Primary Maximum Contaminant Level (MCL)

(3) Safe Drinking Act Secondary MCL

1.3 Report Organization

Following this introductory section, Section 2 presents the site characterization, including a description of the site, summary of the operational and regulatory history, a summary of the site activities and investigations that have taken place and an overview of current site conditions. Section 3 describes the aquifer restoration program implemented by BNSF at Somers under the ROD, including operation and performance of the Phase I groundwater treatment system and current site-wide groundwater quality. In Section 4, the potential for restoration of the aquifer to meet ARARs through alternate groundwater remedies is discussed. Section 5 presents the TI evaluation. Section 6 discusses the recommended action for the Somers site. References are provided in Section 7.

Appendix A to this report contains site-wide geologic cross sections taken from the Remedial Investigation and Feasibility Study (RI/FS) (RETEC, 1989). The results of additional groundwater flow modeling are presented in Appendix B, and contaminant fate and transport analyses are included in Appendix C. Appendix D contains the protocol for statistical analysis of groundwater data developed for the Somers site and the statistical analysis for groundwater data through March 2000. Appendix E contains historical total polycyclic aromatic hydrocarbon (TPAH) groundwater concentrations from site-wide wells.

2 Site History and Characterization

This section of the TI evaluation provides an overview of the Somers site, including a summary of the site operational and regulatory history, source removal activities and site investigations. The complex geologic and hydrogeologic setting of the site is described and sources of contamination remaining at the site after remedy implementation are characterized, since it is this contamination to which a TI waiver would apply. The section concludes with a presentation of the site-wide groundwater conceptual model.

2.1 Site History

BNSF and its predecessors operated a railroad tie treating plant in Somers, Montana, from 1901 until the plant's closure in 1986. The former plant site area covers approximately 80 acres. Wood preservatives used at the plant included creosote, zinc chloride, and for a short time, chromated zinc chloride¹. Throughout its years of operation, the Somers site was used to treat railroad ties and some miscellaneous lumber products with the preservatives listed above. Treatment was conducted in retorts and cylinders. The plant's design capacity for creosote treatment was 10,000 cubic feet of wood per day (RETEC, 1989). The retorts used at the plant through 1986 were those first used for creosote treatment in 1927. The cylinders used at the plant for creosote recovery/evaporative water treatment were the original zinc chloride treatment retorts.

Wastewater generated during the treatment process was disposed of in two locations at the site. During the operation of the Somers plant, BNSF discharged wastewater to the CERCLA lagoon and overflow from this lagoon discharged through an open ditch into Flathead Lake. The discharge of oily wastes was regulated under a permit issued by the Montana State Board of Health (RETEC, 1989). Prior to 1946, a pond formed in the area adjacent to Flathead Lake and waste material discharged through the open ditch accumulated here. This area was termed the "swamp pond." In 1971, the CERCLA lagoon and ditch were abandoned, and in 1984, they implemented a recycling program to eliminate all wastewater discharges. Two new wastewater lagoons were then constructed to the north of the retort. These lagoons were constructed in 1971 and, as such, were subject to regulation under the Resource Conservation and Recovery Act (RCRA). Because of this, they were referred to as the RCRA impoundments. The RCRA impoundments were used for wastewater disposal until 1984. At this time, a

¹ Records from the Somers site indicate that zinc chloride was used exclusively for treatment from 1901 through 1926. In 1927, following a major plant modification, creosote was used along with zinc chloride. Zinc chloride and creosote were both used through 1943, after which time creosote was the only preservative used. Chromated zinc chloride was used for a brief period in 1940 to 1943 (RETEC, 1989)

recycling system was implemented at the Somers tie plant, and all wastewater discharge was halted (EPA, 1989).

The CERCLA lagoon was the basis for the initial EPA Superfund designation of the Somers site in 1984. In February 1984, the Montana Department of Health and Environmental Sciences (MDHES) sampled soils in the CERCLA lagoon. Based on these results, EPA proposed the Somers site for inclusion on the National Priorities List (NPL) in October 1984 (49 CFR 40320, October 15, 1984). The proposed listing cited "potential negative effects on Flathead Lake and the water supply for the town of Somers, which is drawn from the lake" (EPA, 1989).

2.1.1 Summary of Site Investigations

In March 1984, BNSF initiated a series of remedial investigations at the Somers site. The 1984 Phase I investigation involved the installation of 16 groundwater monitoring wells, soil and waste sampling, groundwater sampling and the sampling and analysis of drinking water supplies.

The 1987 Phase II investigations involved additional waste sampling and analysis; the installation of 15 new groundwater monitoring wells at nine locations; three rounds of groundwater sampling; soil and sediment sampling; sampling of surface water in the slough north of the plant site, in Flathead Lake and in Swan Lake; evaluation of air quality data and impacts; two rounds of sampling of the municipal water supply and of private wells; assessment of the potential for contaminant uptake by cattle and by waterfowl; and bioassay studies using sediments from Flathead Lake. Additionally, as a part of the Phase II investigation an incineration test burn of creosote contaminated soils was conducted at a RCRA incineration facility. Groundwater from the site was collected for laboratory treatability testing and land treatment studies were conducted using creosote contaminated soil at the BNSF RCRA facility in Paradise, Montana.

The 1988 Phase III investigation involved installation of three groundwater monitoring wells, three rounds of groundwater sampling, installation of three piezometers, soil sampling in nine test pits and soil investigation in numerous test pits, aquifer testing and groundwater modeling, and additional sampling of Flathead Lake and the slough.

These investigations found that groundwater within the CERCLA lagoon and a portion of the swampy area (referred to as the swamp pond) contained creosote oil. Creosote oil is a dense, nonaqueous-phase liquid (DNAPL). DNAPLs are liquids which are more dense than water and do not readily mix with water. Because they are denser than water they can sink in the aquifer and collect in lithologic changes in the subsurface. The presence of DNAPL poses unique challenges to groundwater cleanup.

2.1.2 Previous Source Removal Activities

In May 1985, EPA issued an Administrative Order for Immediate Removal² for the cleanup of the swamp pond. In response to this order, BNSF removed contaminated soils and water from the swamp pond and a portion of the discharge ditch. Following this, an Administrative Order on Consent³ for additional investigations and a feasibility study (FS) was signed by BNSF, the Sliters Corporation, and EPA in October 1985.

In 1985, BNSF implemented an emergency removal action in the swamp pond area under an Administrative Order for Immediate Removal with EPA. This area was determined to represent an imminent and substantial threat to Flathead Lake because of the presence of heavy creosote contamination in water and soil within 20 feet of the shoreline. Under the Administrative Order, BNSF removed approximately 3,000 cubic yards of the most heavily contaminated soil and over 100,000 gallons of contaminated water from the swamp pond area and a portion of the drainage ditch. During the emergency removal action, an average depth of 1 to 2 feet of the swamp pond was excavated (RETEC, 1989). The contaminated water was treated at the Somers plant, and contaminated soil was transferred to BNSF's RCRA-regulated facility in Paradise, Montana for treatment. Land treatment of the swamp pond soil at Paradise began in 1989 and closed in 1995.

In April 1988, a small area of creosote contamination on the surface of the beach sediment was noted by a local resident. The area was investigated by BNSF and EPA and the presence of the contamination was confirmed. On further investigation, BNSF found that the area of contaminated beach sediment ran approximately 30 feet along the riprap wall and 20 feet out into the beach in a semicircular pattern (RETEC, 1989). Contamination was limited to the surface of the sediment, and was not encountered at a depth of greater than 1.5 feet. In May 1988, the contaminated area was excavated to a depth of 24 to 30 inches at the center, and 12 to 18 inches at the edges. Approximately 40 cubic yards of contaminated sediment was removed and placed in the CERCLA lagoon (RETEC, 1989). The excavation was backfilled with clean material.

Following the beach excavation and removal, a large test pit 20 feet long by 6 to 8 feet deep was excavated alongside the riprap wall on the inland side. An area of creosote-contaminated soil was found in the eastern portion of the test pit and a groundwater seep appeared to enter from the west. In an effort to prevent further migration along this seep, HDPE liner was placed along the lakeside wall of the test pit (RETEC, 1989).

² Docket Number VIII-85-02.

³ Docket Number CERCLA-VIII-85-07.

2.2 Summary of the 1989 ROD

Three remedial investigations (RIs) (referred to as Phase I, Phase II, and Phase III) have been conducted at the Somers site to evaluate the nature and extent of contamination associated with plant operations and to gather the data necessary to support the development of the Feasibility Study (FS). Options for cleanup of soil and groundwater at the Somers site were identified and evaluated in the FS. A time line of significant site and regulatory events is provided in Table 2-1.

2.2.1 Soil Remedies Evaluated in the ROD

The response objective for soil remediation is to reduce exposure from direct contact to an acceptable level and to ensure that the migration of contaminants to groundwater is minimized. The ROD evaluated five alternatives, including the No-Action Alternative. Soil remediation technologies considered were:

- excavation and on-site biological treatment
- excavation and off-site biological treatment
- excavation, stabilization and on-site disposal
- excavation and on-site incineration

Each alternative evaluated both partial excavation and deep excavation and varied the size of the on-site treatment unit to optimize the treatment time for soils.

The Remedial Design Investigation (RDI) Report (RETEC, 1991) further defined the distribution of contaminants in the soil and evaluated land treatment of site soil in the laboratory. The RDI determined that:

- highly impacted soil (i.e., soil containing greater than 5,000 ppm TPAH) resided solely in the upper 15 feet of the CERCLA lagoon
- moderately impacted soil (greater than 1,000 ppm TPAH) can be found at a depth of 15 feet in the CERCLA lagoon and in portions of the former swamp pond
- PAH concentrations in soil in excess of 100 ppm can be found downgradient of the CERCLA lagoon to a 25-foot depth and in the former swamp pond to a 20-foot depth
- biodegradation studies demonstrated that land treatment would effectively remove 95 percent of total PAH in site soil in two treatment seasons

Table 2-1 Time Line of Site and Regulatory History

Date	Activity
1901	Start of Somers Tie Plant Operations (using zinc chloride)
1927	Use of creosote as a treating preservative is initiated
1940	Use of chromated zinc chloride as a treating is initiated
1943	Use of zinc chloride and chromated zinc chloride as a treating preservative is discontinued
1971	CERCLA Lagoon and Discharge Ditch are Abandoned in Place Construction of the RCRA Impoundments
1984	Sampling of CERCLA lagoon soils by MDHES Somers Tie Plant is Proposed for NPL listing Use of RCRA Impoundments Discontinued
1985	Administrative Order for Immediate Removal (Docket No. VIII-85-02) is signed Administrative Order on Consent (Docket No. CERCLA-VIII-85-07) is signed Emergency Removal Action for Swamp Pond Area Phase I Remedial Investigation (ERT)
1986	Administrative Order on Consent Becomes Effective Somers Tie Plant Closes
1987	Phase II Remedial Investigation
1988	Phase III Remedial Investigation Closure of the RCRA Impoundments
1989	Remedial Investigation/Feasibility Study Report (RETEC) Exposure Endangerment Report (RETEC) Record of Decision for the Burlington Northern (Somers Plant) Superfund Site
1991	Remedial Design Investigation (RETEC)
1993	Soil Excavation Start of Land Treatment Operations
1994	Start of Phase I Groundwater Treatment System
1998	Phase II Groundwater Remedy Report (ThermoRetec) Clean Closure of the RCRA Impoundments

Specified Soil Remedy

The response objectives for the soil remedy, as given in the ROD, were to reduce exposure from direct contact to an acceptable level and to ensure that the migration of contaminants to groundwater is minimized. The remedial action specified for soil in the ROD and later modified in the 1992 ESD was the excavation and treatment in an on-site land treatment unit (LTU). The criteria for excavation was to continue all excavation until the unsaturated zone of excavated areas contained carcinogenic PAH (CPAH) at or below 3.6 mg/kg and zinc concentrations at or below 15,750 mg/kg. In the saturated zone, the excavation criteria was 1000 mg/kg total PAH. Creosote and zinc contaminated soils in the CERCLA lagoon, drip track, drainage ditch, swamp pond, beneath the retort (Tie Plant) building and along the slough bank were targeted for excavation. Excavated areas were required to be backfilled with clean borrow soils and revegetated. Figure 1-2 presents the locations of historical site features.

Following excavation, the impacted soils and sediment were to undergo treatment within an on-site LTU. Soil left below the water table in the CERCLA lagoon and swamp would be treated as part of the groundwater component of the remedy. The remedy also included replacement or restoration of wetlands excavated during the remedial action.

Soil Remedial Action

To implement the soil remedy, approximately 53,500 cubic yards of contaminated soil and sediment were excavated from the drip track, retort building, CERCLA lagoon, drainage ditch from the CERCLA lagoon to the swamp area, slough bank, and swamp areas. Figure 2-1 shows the soil volumes excavated at various locations at the site. Soil excavation activities are summarized in *Construction Completion Report for Land Treatment Facility Construction and Contaminated Soil Excavation - Somers, Montana* (RETEC, 1993).

Soil and sediment were treated in the LTU, which is a 14-acre lined facility with capacity for treating 17,900 cubic yards of soil per 1-foot lift. Three lifts of soil have been treated since startup of the LTU in 1994. These lifts are comprised of the original excavation volume of 53,500 cubic yards discussed above, and additional soil from the clean closure of the RCRA impoundments in 1998. Treatment of the final lift of soil began in the summer of 1998 and was completed in the summer of 2000.

The second component of the soil and sediment remedy specified in the ROD was the "restoration and/or replacement of wetlands lost during the 1985 emergency action." To meet this requirement, BNSF is pursuing the expansion and improvement of site wetlands.

2.2.2 Groundwater Remedies Evaluated in the ROD

The response objective for groundwater remediation is to reduce, by treatment, potential exposures from groundwater ingestion and to ensure contaminants in groundwater do not adversely affect the quality of Flathead Lake. To accomplish this objective the ROD evaluated the No Action alternative (institutional controls and long term groundwater monitoring) and three groundwater treatment alternatives. The three groundwater treatment alternatives evaluated were:

- Hot water flushing with physical and chemical treatment of groundwater
- In situ biological groundwater treatment
- Hot water flushing with in situ biological treatment

The 1991 RDI conducted studies on in situ treatment of groundwater. These studies concluded that while hot water flushing would effectively reduce the level of soil contamination in the area of the CERCLA lagoon, excavation of the most heavily contaminated soil would meet the remediation levels in significantly less time. The area downgradient of the CERCLA lagoon was amenable to in situ biological treatment without hot water flushing and the soil below the water table in the swamp pond was not amenable to in situ treatment with water flushing. Again it was determined that the treatment time for the swamp pond soils would be less if the most heavily contaminated soil was excavated and treated on site.

Specified Groundwater Remedy

The groundwater remedial action specified by the ROD was the installation of a pump and treat system to "remove available free creosote contamination from the water table aquifer in the CERCLA lagoon and swamp pond areas" (EPA, 1989). The second aspect of this remedial action was to conduct "in-situ biological treatment to degrade both contaminants adsorbed onto the aquifer matrix and residual contaminants dissolved in the groundwater" (EPA, 1989).

The ROD also called for a groundwater remedy to restore the surficial aquifer at the site within 50 years. The period of 50 years was considered the maximum "reasonable" period of time. Cleanup projects with a duration of greater than 50 years are often considered to be difficult to design and manage.

The selected remedy was to include a phased approach based on several innovative groundwater remediation technologies. The initial phase of groundwater cleanup was based on use of a hot water flushing technique to

remove oily creosote wastes (i.e., DNAPL). The final phase of groundwater cleanup would then occur using in-situ biological treatment. The ROD recognized both the undemonstrated status of these technologies and the complex hydrogeology of the Somers site as issues to be resolved during remedial design of this alternative. These issues were examined as part of the Remedial Design Investigation (RETEC, 1991).

The RDI determined that flushing the aquifer with hot water was not a practicable component of the Somers groundwater remedy. While significant removal of oily wastes occurred in some of the soils evaluated in the laboratory, those soils contained a high concentration of PAHs and were not representative of conditions encountered across most of the area requiring treatment. The RDI recommended, and EPA concurred (ESD, 1992), that a more effective option would be to excavate this additional volume of soil. It was concluded that in-situ biological treatment could be an effective means of groundwater cleanup for the mass of contaminants remaining after excavation.

The ROD included provisions for groundwater monitoring and post-closure care for up to 30 years or placement of deed restrictions if hazardous constituents remain above the risk-based, ROD remediation levels. Details of the Phase I Groundwater Treatment system operation and effectiveness are given in Section 3.

2.3 Geology and Hydrologic Setting

The geology and hydrogeology of the Somers site have been thoroughly characterized in earlier investigations (ERT, 1985; RETEC, 1989). The following site description presents the most up-to-date geologic and hydrogeologic characterization of the Somers site. Data from nearly 100 monitoring wells, borings, piezometers, and test pits, six extraction wells and 14 injection wells comprise the database used to describe the stratigraphy and hydrogeologic regime at Somers. Visual observations of the stratigraphy underlying the site during source removal activities supplement this database. Operation of the Phase I groundwater remedy also provides valuable data regarding hydrogeologic conditions at the site.

2.3.1 Geologic Setting

Regional geology and site-wide geology are discussed below, followed by a discussion of geology specific to the CERCLA lagoon area. The geology of the CERCLA lagoon area is important to this TI evaluation since this is the primary area of groundwater contamination at the site. The Geologic Setting section concludes with a description of the bedrock underlying the site.

Regional Geology

The regional geology of the Flathead Valley has been the subject of several investigations. The information presented below is taken from the studies completed by Konizeski (1968) and Noble (1986) for the State of Montana Bureau of Mines and Geology in association with the U. S. Geological Survey.

The Somers site is located on the west side of the Kalispell Valley. The Kalispell Valley, a trench-like depression formed by down faulting of the basement Precambrian rocks during late Paleocene-Eocene time, was partly filled with material eroded from the nearby mountains during Tertiary time (Konizeski and others, 1968). In Pleistocene time the sediments of Tertiary age were partly eroded and the remnants were buried beneath ice-contact and glaciolacustrine deposits. As the ice from the last glacial stage melted, Lake Missoula expanded northward and the Kalispell Valley was inundated. Sand, silt, and clay (glacial flour) were deposited in Lake Missoula. While the lake was receding about 12,000 years ago, the Flathead River and its tributaries entrenched their courses about 100 feet into the unconsolidated valley-fill deposits. The flood plains were subsequently broadened and graded to the level at which the lake had stabilized. Gravity data indicate a maximum depth of about 4,800 feet of valley-fill deposits of Tertiary and Quaternary age (Konizeski and others, 1968).

A variety of sequential post-glacial events is reflected in the geologic complexity of the lower Kalispell valley in the general vicinity of the Somers site. Prior to the Flathead River establishing its present channel, the river flowed into Flathead Lake near Somers. A chain of small ponds and sloughs are aligned along the former river course. The geomorphological characteristics of tight meander bends and associated point bar deposits of this abandoned channel imply a fluvial, aggrading depositional environment. In addition, the area north of Somers is 10 to 20 feet higher topographically than the rest of the Lower Valley. Bathymetric maps show that an ancient deltaic lobe extends approximately two miles out from the present lakeshore in Somers Bay. The size of the ancient deltaic lobe suggests that the former river channel was well established. Noble's report provides a map displaying the deltaic deposits in the Lower Valley (Figure 7, in Noble, 1986). In areas abandoned by the river as it changed its course, sediment influx would be diminished causing the previously deposited sediment to be reworked by the action of the lake.

A grid of 13 monitoring wells was installed throughout the Lower Flathead Valley (Noble, 1986). Geologic logs displayed a sedimentary sequence common to deltaic deposits. The topsoil profile is 0.5 to 1.0 feet thick and overlies a silt bed that averages two to three feet thick. Underlying the silt is a fine- to medium-grained sand or silty sand. The sand varies from three to

eight feet in thickness. Underlying the silty sand is a sandy and clayey silt that varies in thickness from five to 100 feet. This lowest unit consists of inter-bedded sediments of deltaic and lacustrine origin.

Site-wide Geology

The geology of Somers is complex due to the interbedded nature of sediments resulting from different depositional environments. The Somers site is located in Flathead Valley and consists of glacial deposits from the Salish Mountains as well as fluvial deposits reworked by the Flathead River. Furthermore, much of the site from Somers Road to the former swamp pond is believed to have been previously covered by Flathead Lake. As a result of these depositional environments, the geology consists of fine-grained, discontinuous and interbedded silt, sand and clay stratigraphy. Cross sections depicting site-wide geological conditions were originally presented in the RI/FS report (RETEC, 1989). The cross sections have been reproduced here in Appendix A to aid in demonstrating the heterogeneity of the geology at the site. It is important to note that the cross sections represent subsurface conditions prior to the implementation of the soil remedy. A cross section location map is provided as Figure A-1.

The stratigraphy underlying the site has been subdivided into four units. The upper unit is comprised of fill up to 10 feet thick and consists primarily of gravel with some sand, silt, and clay. The fill is underlain by a unit consisting of sandy silt and silty sand that ranges in thickness from 0 to 25 feet that decreases in thickness towards the lake. The upper portion of this unit is a sandy silt and grades downward into a silty sand. Discontinuous well-sorted sand lenses are present in this layer. Underlying this sandy silt layer is a 60- to 70-foot-thick finer-grained unit primarily comprised of silt with some fine-grained sands and clays. Thin, occasional and discontinuous sand lenses are present to depths of approximately 45 feet bgs. Finally, this fine-grained unit is underlain by Precambrian bedrock. Based on visual observation of the outcrops west of the site, the Precambrian bedrock is believed to be gray, silty, stromatolite-bearing dolomite, a part of the Piegan Group. While these four units are generally present throughout the site, the lack of correlation is apparent in the following comparison of site-wide cross sections.

In the northern portion of the site in the vicinity of the former plant and LTU, all four units are present (refer to Figures A-2 and A-3). The fill is approximately 10 feet thick, the sand and silt unit is approximately 25 feet thick, and the silt unit is 60 to 70 feet thick. In particular, the sand and silt unit contains the discontinuous sandy-silt layers that are attributed to the reworking of underlying glaciolacustrine sediments in which the finer particles (clays and silts) were winnowed upward through river action.

In the center of the site (CERCLA lagoon area) and closer to the lake, the fill is absent (except in the lagoon itself; refer to Figures A-4 through A-7). The silty upper portion of the silt and sand unit is missing and the sand unit is approximately 15 feet thick and thins towards the lake. The underlying silt, containing varying amounts of sand and clay, is 60 to 70 feet thick.

South of the former Tie Plant, the gently sloping swamp area consists primarily of discontinuous inter-fingering lenses of clayey and sandy silts, and silty clays with traces of sand. Figure A-5 illustrates the variation in silt lithologies from a northeast-southwest direction.

It is apparent by comparing the different cross sections throughout the site, that while the four units described above are generally present, distinct contacts between the units are not always discernable. In some areas of the site, slight gradational changes may be the only distinguishing feature between two units with similar grain size. This lack of distinct layering and discontinuous nature of the sediments suggest the reworking of the underlying glaciolacustrine materials, which is responsible for the complex and heterogeneous geology at Somers.

Geology in the Vicinity of the CERCLA Lagoon

The surficial unconsolidated deposits in the area of the CERCLA lagoon consist of mixtures of silt, clay, and fine sand, with infrequent sand lenses varying in thickness from 3 inches to 1.5 feet. The upper 15 feet of the former CERCLA lagoon is occupied by fill placed after the 1993 excavation. The fill consists of silty sand with some small cobbles and gravel. Surrounding and underlying the fill is a gray fine sandy silt with small amounts of clay, corresponding to the silty sand unit (the second unit from the ground surface described above). In the area surrounding and underlying the CERCLA lagoon excavation, root traces are observed to a maximum depth of about 20 feet below ground surface (bgs). While a few root traces were noted elsewhere at the site, they were found to be concentrated in the CERCLA lagoon area.

Underneath these deposits, clayey silt or silty clay with sand, corresponding to the silt unit described above, was observed during the installation of boring BH-3 to a depth of about 55 feet. From 55 to 96 feet, silty clays with no sand were encountered. At a depth of 105 to 106 feet, a very tight clay containing pieces of shale was observed. At this point, refusal to drilling occurred, and it was assumed that bedrock was reached.

Bedrock Surface Topography

Changes in geology can control the migration of DNAPL, or sinking product. The bedrock surface discussed above as the fourth unit encountered beneath the Somers site represents such a change. If present in large enough quantity

(i.e., a pool) on the bedrock surface, DNAPL would flow in response to gravity. Thus, the topography of the bedrock surface is important to understanding the potential for DNAPL migration at the site. It is important to note, however, that a DNAPL pool has never been encountered at the site and the CERCLA lagoon excavation is believed to have removed well over 50 percent of the residual and free-phase contaminant source at the site (see Section 2.4).

Figure 2-2 is a top of bedrock contour map for the Somers site. The upper surface of the bedrock dips to the east. As a result bedrock elevation is higher to the west and lower to the east of the former CERCLA lagoon. The bedrock surface slopes to the east or northeast away from the municipal water supply well, which is located approximately 1,300 feet southwest of well S-85-8. A total of eleven existing or abandoned wells and borings were used to develop the map. An additional two wells were of sufficient depth that they were used as guides for the depth to bedrock. Boring BH-3 provides control at the location of the former CERCLA lagoon. Bedrock under the lagoon was encountered at an elevation of approximately 2,805 feet MSL. In the area of the CERCLA lagoon, the bedrock surface dips generally to the east. With minor localized variations, this eastward dip is the general trend across the site. Well S-7, located west of the CERCLA lagoon and boring BH-3, located in the CERCLA lagoon, were used to determine the slope of the bedrock surface. Well S-7 was terminated when reached a clayey, sand containing gravel, assumed to be the gravel above the bedrock surface. There is an approximate 100-foot difference between the bedrock elevations at these two locations. This translates to a bedrock slope of approximately 0.16 feet per foot (ft/ft). A sandy, clayey gravel of approximately 10 feet thick was observed above the bedrock from the CERCLA lagoon area towards the lake.

2.3.2 Hydrogeology

Two distinct aquifers have been identified at Somers—the surficial aquifer and the bedrock aquifer. The surficial aquifer is a water table aquifer with low hydraulic conductivity that occurs within the fine-grained interbedded silt, clay, and sand described above (units one through three). Site-specific estimates of hydraulic conductivity range from 0.046 ft/day to 1.64 ft/day. Groundwater flow occurs predominantly through the sand lenses. However, since the sand lenses are thin and discontinuous, the groundwater flow paths are not uniform, but rather short and tenuous. The limited paths available for groundwater flow in combination with the overall low permeability result in low water yield. The bedrock aquifer exists under confined to semiconfined conditions and occurs within the fractured bedrock and overlying gravels. The groundwater remedy at the Somers site only addresses the surficial aquifer although, monitoring of the bedrock aquifer is included in the site monitoring plan.

Groundwater Flow Direction

Groundwater in the water table aquifer in the vicinity of the former RCRA impoundments flows northeasterly towards the slough. In this area, the water table is not affected by water level fluctuations in Flathead Lake. In the vicinity of the CERCLA lagoon, groundwater flows southeast towards Flathead Lake. The water table in this area of the site is affected by the water level in Flathead Lake. Groundwater is encountered at a depth of approximately 16 to 18 feet bgs in the area of the former CERCLA lagoon and the LTU, and a depth of approximately 2 feet bgs near Flathead Lake. The seasonal groundwater table fluctuation at the site is approximately 1 foot. Groundwater potentiometric maps showing seasonal variations in groundwater elevations are presented in Section 3 in conjunction with evaluation of the performance of the Phase I groundwater treatment system.

Review of hydrographs for site monitoring wells and lake level (Figure 2-3) suggest that both the bedrock and surficial systems discharge to the lake. However, it is apparent that the lake discharges to the surficial aquifer during the fall measurement events (for the past 7 years). The lake level is artificially controlled by Kerr Dam at the south end of the lake. Under agreement with the Flathead Lakefront property owners, the lake level is raised to reach full pool by June 15 of every year. The lake level is maintained at full pool until after Labor Day, although this is dependent on weather and the demand for power, and may stay at full pool throughout the fall. In the fall, the lake level is artificially dropped to 10 feet below full pool to 2,883 feet mean sea level (MSL), to create storage for snowmelt and spring runoff. The fall measurements are the result of the elevation of the lake level creating a condition where the lake recharges the surficial aquifer. During the spring the lake level is lowered to allow for snowmelt and precipitation. During this time, when the lake level is lowered, the surficial aquifer discharges to the lake. The magnitude of the fluctuation in the surficial aquifer is progressively less with distance from the lake. This is observed in water level measurements taken in wells further from the lake S-85-8a, S-85-6 (ThermoRetec, 2000). In addition, with the seasonal gradient reversal, the potential transport of chemicals is also reversed. The RI/FS (RETEC, 1989) included sampling and analysis of Flathead Lake, Flathead River and a background lake, Swan Lake, to evaluate potential site impacts to surface water. The results of this study indicated that there was no effect from carcinogenic PAH compounds and concentrations of non-carcinogenic PAH compounds were below water quality criteria. Consequently, remediation levels pertinent to surface water were not established in the ROD. Since no PAHs are present in the bedrock well near the lake, the recharge/discharge relationship between the lake and bedrock aquifer will not impact contaminant migration.

Vertical Gradient

A vertical gradient analysis was presented in the Phase I Groundwater Remedy - Annual CERCLA Report (ThermoRetec, 1999). Vertical groundwater flow was documented by collecting data from nested wells (wells completed at different depths in close proximity to each other). At the Somers site, two sets of nested wells are used; wells S-85-6a and S-85-6b located east of the CERCLA lagoon area and wells S-84-10 and S-91-4 in the swamp area. The surficial aquifer is categorized by wells S-85-6a and S-85-6b, which are screened 20 vertical feet apart, and as such, are suitable for analysis of vertical gradients in the shallow aquifer. The well pair selected to examine vertical gradients in the swamp area is comprised of one shallow well (S-84-10) and one bedrock well (S-91-4); the two wells are screened over 80 vertical feet apart.

The Bedrock and surficial aquifer show a similar pattern with the bedrock aquifer recharging the surficial aquifer in the fall and to a lesser degree the surficial aquifer recharging the bedrock in the spring.

2.3.3 Surficial Aquifer Characterization

Surficial aquifer characterization, conducted as part of the RDI, included the performance of aquifer constant-discharge tests and the laboratory analysis of soil cores. The hydraulic conductivity of the area downgradient of the CERCLA lagoon area was calculated to range from 5.7×10^{-3} to 7.39×10^{-4} cm/sec with an average conductivity of 1.46×10^{-3} cm/sec (RETEC, 1990). A fairly similar conductivity value of 2.88×10^{-3} was estimated using the laboratory saturated hydraulic conductivity test. Groundwater modeling was performed in conjunction with the Final Phase II Groundwater Remedy Remedial Design (RETEC, 1998) to revise the pre-remedy implementation hydraulic conductivity estimates based on actual groundwater extraction rate and aquifer drawdown data generated through operation of the Phase I groundwater remedy. The modeling effort is detailed in Appendix B, and operation of the Phase I groundwater remedy is described in Section 3. Based on the results of this groundwater modeling, a conductivity value of 3.5×10^{-4} cm/sec is the most reasonable value for characterization of flow at the site.

During the constant-discharge tests conducted during the RDI, the maximum sustainable pumping rate in the wells downgradient of the CERCLA lagoon area varied from 0.5 gallons per minute (gpm) to 2.0 gpm at a 100-foot distance. This variability is indicative of the heterogeneity of the site geology, particularly as it pertains to the location and areal extent of the sand lenses. The sand lenses, although limited in size and interconnectedness, are believed to be the primary pathways for the limited groundwater flow that occurs in this area. Injection testing of water to the surficial aquifer during the RDI indicated that reintroducing water back into the aquifer would not be a

limiting factor. However, actual operations indicate that the hydraulic conductivity of the surficial aquifer is at the lower end of the range reported in the RDI and that injection through individual well points is very limited by subsurface conditions. A discussion of the amount of treated water that can be reinjected to the subsurface is provided in Section 3.

2.4 Source Characterization

The 1989 ROD identified areas of the site for excavation and treatment of PAH contaminated soil. Areas identified for soil removal were: the CERCLA lagoon, the swamp pond area, the drip tracks, retort, the drainage ditch and the slough. The ROD acknowledged that creosote contamination in soil, below the water table would remain in-place to be treated as a part of the groundwater remedy. Source removal activities conducted at the Somers site prior to implementation of the ROD are described earlier in Sections 2.1. This section provides an estimate of the mass of contaminants removed through the soil remedy implementation and describes the nature and extent of contamination remaining after implementation of the soil remedy.

2.4.1 Source Removal

The former CERCLA lagoon was the primary source of groundwater contamination at the site. As part of the soil remedy, extensive soil excavation was conducted in 1993 to remove the most highly contaminated soil in the immediate area of the former CERCLA lagoon and the swamp. The criteria for excavation were to continue all excavation until the unsaturated zone of excavated areas contained CPAH at or below 3.6 mg/kg and zinc concentrations at or below 15,750 mg/kg. In the saturated zone, the excavation criteria was 1000 mg/kg total PAH. Both the side walls and bottom of the excavation areas were sampled to confirm that the excavation criteria were met. This soil excavation also served to remove a source of groundwater contamination.

Contaminated soil in the CERCLA lagoon area was excavated to a maximum depth of 15 feet; approximately 22,300 cubic yards of contaminated soil were removed. Assuming that the excavated soil contained an average concentration of 2,000 milligrams per kilogram (mg/kg) total PAH (based on soil treatment sample results) and had a soil bulk density of 100 pounds per cubic foot (2,700 pounds per cubic yard), then approximately 60 tons (120,420 pounds) of PAHs were removed from the CERCLA lagoon area during the 1993 excavation. Soil removal also eliminated a large potential continuing source of groundwater contamination. The average excavation soil concentration (2,000 mg/kg total PAH) is conservative since it includes lower concentration swamp excavation soils. These soils have been treated on site in the LTU over the last 5 years.

Impacted soil was also excavated in the swamp pond as part of source removal. The swamp pond excavation covered an area of 0.98 acres to the top of the water table, which was an average depth of 12 feet bgs. During excavation sheet piling was installed along the edge of the swamp pond bordering Flathead Lake to both protect the Lake from migration of creosote and minimize surface water intrusion into the pond. A dewatering system was installed in the swamp pond area to increase the overall depth of excavation and ensure that the most contaminated soils were removed. The horizontal extent of excavation was determined by sampling and analysis to ensure that all soil exceeding the 3.6 mg/kg CPAH remediation level was removed.

Approximately 19,000 cubic yards of swamp pond soil was removed and treated with the 22,300 cubic yards of CERCLA lagoon soil in the LTU. The Remedial Design Investigation (RETEC, 1991) detailed the soil concentration at depths of ten and twenty feet bgs. The RDI soil concentration data was used to estimate the mass of total PAH removed by the swamp pond excavation. The top ten feet of swamp pond soil contained the highest concentrations of PAH, with an average of 1,278 mg/kg total PAH. The 10- to 20-foot interval had an average concentration of 360 mg/kg total PAH. The 19,000 cubic yards removed consisted of the top 12 feet of swamp pond soil. In all approximately 29 tons of total PAHs were removed, from the swamp pond and treated on the LTU.

2.4.2 Residual PAHs in Soil

The RDI estimated 139,157 cubic yards of impacted soil on the Somers site. After extensive excavation in the CERCLA lagoon and swamp pond areas, approximately 62 percent of the total PAH compounds in soil were removed with excavation of 30 percent of the soil mass. Of the original estimated volume of contaminated soil, 70 percent remains on site, and contains approximately 38 percent of the original mass of contaminants. To estimate the mass of PAHs remaining, the areas of concern were divided into: 1) a 300-foot by 150-foot area around the extraction/injection wells to the north of Somers Road, and 2) a 200-foot by 100-foot area around the extraction/injection wells to the south of Somers Road. An estimated 66,670 cubic yards of contaminated soil in Area 14, located from 15 feet to 55 feet bgs. Another 18,520 cubic yards remains from 15 to 40 feet bgs in Area 25. Assuming a soil bulk density of 2,700 pounds per cubic yard and an average concentration of 500 mg/kg total PAH for Area 1 and 150 mg/kg for Area 2, about 50 tons (97,500 pounds) of PAHs remain in soil. In 1993, approximately 22,300 cy of soil were removed from the CERCLA lagoon. This represented a removal of 21 percent of the impacted soil volume and over 55 percent of the total PAH mass in the soil. Removal of the remaining

⁴ Contaminated soils were found at depths of 55 feet in the CERCLA lagoon during recovery/injection well installation in 1993.

⁵ Contaminated soils were not observed below a depth of 40 feet during the 1991 RI.

45 percent of the total PAH mass in soil would require excavation to depths as great as 55 feet bgs and result in almost four times the volume of soil which has already been excavated and treated (Table 2-2).

The concentration of PAH remaining as residual creosote contaminated soil beneath the water table in the swamp pond is a minor contributor relative to the mass of PAH remaining in the CERCLA lagoon. Following source removal, groundwater monitoring results in the vicinity of the swamp pond have been below target clean-up levels. The mass calculations for PAHs remaining in the swamp pond follow a similar calculation as above. The areal extent of excavation in the swamp pond was 42,750 ft² the top ten feet of swamp pond soil contained an average total PAH concentration of 1,278 mg/kg, which calculates to a mass of 27.32 tons of total PAH in soil. The two feet below this interval contained on the average 360 mg/kg and excavation of this soil removed approximately 1.54 tons of total PAHs. The swamp pond excavation extended to 12 feet bgs and concentrations of PAHs were documented to 20 feet bgs. Attainment of excavation depths to 12 feet bgs was made possible through a dewatering system. The mass remaining, below the water table, from 12 feet bgs to 20 feet bgs is approximately 6.16 tons of total PAHs. The residual mass of PAH remaining below the swamp pond is approximately one-eighth of the residual mass of PAH remaining in the CERCLA lagoon.

Table 2-2 Contaminant Mass Estimates

Location	Volume (yd ³)	Percentage Total Soil Volume	Contaminant Mass (lbs)	Percentage Total PAH in Soil
Removed				
CERCLA Lagoon	22,300	21%	120,420	55.3%
Swamp Pond	19,000	60%	57,713	82.4%
Remaining				
Area 1 - North of Somers Road	66,670	62%	90,000	41.3%
Area 2 - South of Somers Road	18,520	17%	7,500	3.4%
Swamp Pond	12,667	40%	12,312	17.6%

2.4.3 DNAPL Occurrence

DNAPL is present within the aquifer in root traces, clay fissures and discontinuous sand lenses. It is important to note that a pool of DNAPL was not encountered during any of the investigations or remediation activities conducted at the site. NAPL⁶ (nonaqueous-phase liquid) has been observed in some of the extraction and injection wells (Figure 2-4) sorbed to silt particles present in the water column. On purging of these wells, water removed is typically brownish-yellow⁷ and contains less than 5 percent of a fine dark brown/black silt. The water surface typically contains a slight sheen and has a creosote odor. Small droplets (1 to 2 mm diameter) of creosote product may be visible on the sides of the bailer. A separate NAPL product phase is not observed; therefore the mass of free-phase DNAPL is believed to be relatively small compared to the residual DNAPL mass in soil. However, since there is no measurable thickness of DNAPL, it is very difficult to estimate the amount of NAPL present in the subsurface. Based on experience at other sites, the mass of free-phase NAPL may be in the range of 1 to 10 percent of the total NAPL mass in soil.

2.4.4 Groundwater Treatment System Influent

Phase I of the Somers groundwater treatment remedy was designed to hydraulically contain and treat the most heavily impacted groundwater at the

⁶ The free product observed in wells is not sinking product, or DNAPL, since it is sorbed to silt particles. Therefore, the term "NAPL" is used to describe product droplets observed in groundwater from the site.

⁷ Dissolved iron may contribute to the discoloration of purged groundwater.

site. To characterize and quantify influent conditions from the treatment area, a sample is collected at the influent port from the extraction wells. The Groundwater Remedy Annual CERCLA Report (ThermoRetec, 2000) reported the most recent site-wide groundwater treatment system analytical data and the influent PAH concentrations from the treatment area.

The quality of water processed through the treatment system has not changed appreciably over time (Figure 2-5)⁸. However, greater variability in total semivolatile influent concentrations is observed compared to total PAHs or naphthalene. This may be indicative of reductions in the concentrations of phenolic compounds such as phenol, 2-methylphenol, 4-methylphenol, and 2,4-dimethylphenol within the groundwater. These compounds are more water soluble than the majority of PAHS and are therefore more likely to be removed along with extracted groundwater. The temporary spike in semivolatile organic concentrations in 1998 may be attributed to bringing injection well IW-8 online. This well had previously contained free-phase NAPL, which was removed prior to bringing the well online. However, residual NAPL likely remained in the area surrounding the injection well. Circulation of water through this area may have resulted in a temporary increase in dissolved-phase contaminant concentrations.

The average total PAH concentration in the influent groundwater to the treatment system is 15,381 µg/L, as compared to the 40µg/L total PAH remediation level established in the ROD. Estimating the mass of PAHs associated with the dissolved plume is based on the concentration of groundwater and the areal extent of the plume. The estimated extent of contamination is 110,000 square feet⁹ over an aquifer thickness of 50 feet (based on screen interval length). Assuming an effective porosity of 0.25 for a silty, sandy clay (McWhorter and Sunada, 1997), an impacted area of 110,000 square feet and an aquifer thickness of 50 feet, then 1,375,000 cubic feet of groundwater containing approximately 15.4 milligrams per liter (mg/L) of total PAH, is equal to a PAH mass of 600 kg (1,320 pounds).

2.4.5 Summary of Contaminant Sources

As described above, the estimated mass of residual total PAH contamination adsorbed to soil in the well field region is 97,500 pounds, and approximately 1,320 pounds is dissolved in groundwater. The mass of free-phase NAPL in soil pores is believed to be comparatively low, estimates range between 5percent and 10percent of the pore spaces contain free-phase NAPL. Consequently, the estimated mass of NAPL could range upwards from 97,500

⁸ Note: influent water quality for the periods from March through May 1996 and January through May 1997 represents a combined flow of extracted groundwater and LTU snowmelt from water.

⁹ The area of 110,000 square feet is based on the groundwater surface area over which drawdown from the Phase I treatment system is observed, as discussed in Section 3.3.2.

to 107,250 pounds. These impacted soils are spread over a large area and reside primarily below the water table. The volume of impacted soil remaining is estimated to be 97,857 cubic yards. Excavation of this soil, if it had not been technically impracticable, would have more than tripled the amount of soil for land treatment. The ROD anticipated that soil remaining below the water table would be remediated through implementation of the groundwater remedy.

2.5 Groundwater Conceptual Model

The following groundwater conceptual model describes current conditions at the Somers site, following implementation of the soil remedy and Phase I groundwater remedy. These remedies are described in detail in Section 3. The conceptual model describes the existing source(s) of groundwater contamination at the site, the groundwater beneficial use, the fate and transport mechanisms that may be applicable to the site, and the potential exposure pathways. This conceptual model focuses on groundwater exposure pathways since the soil remedy addressed any exposure pathways directly related to soil (i.e., direct contact with surficial soils).

2.5.1 Sources

As shown in the simplified conceptual model, Figure 2-6, several areas of contamination at the Somers site have been addressed through implementation of the soil remedy. With removal of the impacted soils in the CERCLA lagoon, the major contamination source area was removed, however, residual and discrete, discontinuous droplets of free-phase creosote beneath the excavation zone remain and may act as a continuing source of the dissolved-phase PAHs. Residual product adsorbed to soil will also continue to dissolve in groundwater over time.

2.5.2 Fate and Transport Pathways

The fate and transport pathways applicable to the Somers site are DNAPL migration and groundwater transport. DNAPL is present within the aquifer in root traces, fractures and sand lenses as shown in Figure 2-6. The movement of DNAPL is governed primarily by gravitational forces and capillary pressures. As discussed in Section 2.4, however, DNAPL occurs at the site in discrete, discontinuous droplets; no DNAPL pool has ever been encountered at the site. Therefore, DNAPL migration is not believed to be a pathway of concern for the Somers site.

Groundwater transport of dissolved-phase contaminants is a potential pathway of concern at the Somers site. A dissolved-phase plume is formed through the dissolution of contaminants from a NAPL or residual soil source to groundwater. Unlike DNAPL, the movement of which is governed primarily by gravitational forces and capillary pressures, the fate and transport of

dissolved constituents result from several different mechanisms, which include the following:

- **Advection** - the transport of the constituent molecule with groundwater.
- **Diffusion** - the movement of constituent molecules caused by differences in concentration gradients, i.e., chemicals diffuse from areas of high concentration to areas of low concentration.
- **Dispersion** - the transport of constituent molecules resulting from the flow of groundwater through pathways between soil particles.
- **Sorption** - the slowing or retardation of contaminant transport caused by the binding of organic molecules on soil particles and organic matter.
- **Biodegradation** - the removal of constituent molecules through a biological transformation by naturally occurring organisms. In addition to biodegradation, other loss mechanisms such as hydrolysis and chemical oxidation-reduction are also active.

A combination of advection, diffusion, and dispersion processes results in the formation of a dissolved-phase plume, with dissolved constituents migrating outward from the source area in the direction of groundwater flow. The amount that the plume spreads laterally and vertically is primarily a function of advection combined with diffusion and dispersion. Loss mechanisms, such as biodegradation, affect the extent of the plume, the total plume mass, and the time to reach steady state. The rate at which the plume migrates is also influenced by these factors, but is more predominantly controlled by sorption or, more specifically, retardation. Retardation results from the inherent chemical properties of the contaminant which govern its tendency to bind to organic material. Note that, retardation does not affect the extent of the plume at steady state or the total mass of the plume, but only the time required to reach steady-state conditions. Volatile losses are considered insignificant given the type of compounds and the length of time that has passed since they were released.

Fate and transport modeling is performed in the following exposure assessment to evaluate the potential for dissolved PAHS to be transported in groundwater to potential receptors associated with the beneficial groundwater use.

2.5.3 Exposure Assessment

A fate and transport analysis was performed to determine the potential for contaminants originating from the site to adversely impact the water quality of the town water supply or Flathead Lake. A summary of modeling procedures used to conduct this analysis is provided below along with a discussion of results.

Migration to the Town Well

The potential fate and transport of the contaminants in groundwater at the Somers site was evaluated to assess the potential for these constituents to migrate vertically downward from the area of the former CERCLA lagoon to the bedrock aquifer in which the Town water supply well is screened. This analysis is considered very conservative, since the vertical gradient analysis discussed in Section 2.3.2 indicates an upward gradient between the bedrock aquifer and the surficial aquifer. Additionally, this analysis was conducted using data from 1987, prior to the implementation of the groundwater treatment system and therefore provides an estimation of potential fate and transport in the absence of a pump and treat system.

The following section provides an analysis of the potential impact to the town well by groundwater flowing from the lagoon area. The analysis was completed using naphthalene and benzo(a)pyrene as the PAH constituents of concern. These two compounds are representative of the range of mobility of PAH compounds. Appendix C provides additional detail on the seepage velocity analysis.

Using data from the 1990 pump test on the Somers water supply well (RETEC, 1991), it was assumed that the constituents would migrate from the surficial aquifer to the bedrock aquifer across 25 feet of low permeability clay. Using the difference in head at well nest S-85-8a and S-85-8b of 1.6 feet, the downward vertical hydraulic gradient was estimated to be 0.064 ft/ft across the low permeability clay. The hydraulic conductivity of the low permeability clay was assumed to be 3.3×10^{-7} feet per second (ft/sec) (the estimated value for horizontal conductivity; RETEC, 1989). An effective porosity for clayey silt or silty clay of 0.15 and a soil bulk density of 1.43 grams per cubic centimeter (g/cm³) were assumed (McWhorter and Sunada, 1977; Beljin, 1991). Using these values, the seepage velocity through the low permeability clay was calculated to be 0.012 ft/day.

For estimating the seepage velocity in the bedrock aquifer, aquifer test data from the RI/FS report of April 1989 indicated an average hydraulic conductivity of 4.6×10^{-3} cm/sec for well S-85-8b. Water table elevation data from the Phase II RI dated February 1987 indicated a hydraulic gradient between S-85-1b and S-85-8b of 0.002 ft/ft (prior to installation of the pump and treat system). Values of 0.28 for effective porosity and 1.70 g/cm³ for

soil bulk density of sandy, clayey gravel were assumed (McWhorter and Sunada, 1977; Beljin, 1991). The estimated seepage velocity for the bedrock aquifer was calculated to be 0.093 ft/day by multiplying hydraulic conductivity by hydraulic gradient and dividing by effective porosity (see Section C.1.2 for equation derivation).

Using literature values (EPA Soil Screening Guidance: User's Guide, 1996) for the organic-carbon partition coefficient of naphthalene (2×10^3 liters per kilogram [L/kg]) and benzo(a)pyrene (1×10^6 L/kg) and a conservative value (0.1 percent) for the fraction of organic carbon, retardation factors for the respective constituents were calculated to be 13 and 6,072.

For analysis, it was assumed that the contaminants traveled through the 25 feet of low permeability clay in the vicinity of well S-85-8b and 1,300 feet of bedrock aquifer to the town well. Based on the appropriate solute velocity equations, the estimated time of travel through the low permeability clay was approximately 74 years for naphthalene and 34,700 years for benzo(a)pyrene. The estimated time of travel through the bedrock aquifer toward the town well was approximately 500 years for naphthalene and 230,000 years for benzo(a)pyrene. Given these estimates of travel time, one may assume that neither constituent would reach the town well. Historical water quality data for the town well concur with this analysis as PAH constituents have never been detected at part-per-trillion detection limits.

Migration to Flathead Lake

An analytical contaminant transport model based on the Domenico Solution (Domenico, 1991) was used to estimate the attenuation of contaminants of concern (COCs) between the source area and Flathead Lake. The Domenico model has some very conservative underlying assumptions:

- Uniform and constant aquifer properties;
- One-dimensional groundwater flow;
- First-order contaminant decay, degradation, or transformation; and
- Constant contaminant source of rectangular cross section in the plane perpendicular to groundwater flow.

At the Somers site, aquifer properties vary due to the heterogeneous, interbedded stratigraphy. In addition, groundwater flow is not one-dimensional, but rather occurs both vertically and horizontally in tenuous paths. However, the assumptions of uniform and constant aquifer properties and one-dimensional flow are conservative and hence, protective, since they result in overestimates of the actual rate and extent of contaminant transport.

In general, application of the Domenico solution is appropriate where a dissolved-phase plume has reached steady state (i.e., constant source), or is diminishing. In the case of the Somers site, the dissolved-phase plume does not appear to be changing as discussed in Section 3.2.

The model predicts the maximum centerline groundwater concentration in a contaminant plume under steady-state conditions. Attenuation was modeled based on biodegradation and longitudinal, transverse, and vertical dispersion. A conservative value was chosen for the half-life of the COCs (naphthalene and benzo(a)pyrene).

Attenuation of COCs is partly a function of groundwater travel distance. The travel distance from the source area to Flathead Lake was estimated to be 1,000 feet based on the site map. This distance served as the "distance to receptor" input for the fate and transport analysis.

Naphthalene was chosen as the indicator compound for the site since it is the most mobile of the PAH constituents. Model input parameters and output are provided in Appendix C. The estimated time for naphthalene to reach Flathead Lake is 5,000 years. In 5,000 years the model estimates that less than 1 µg/L of naphthalene will reach Flathead Lake from the CERCLA lagoon area. Surface water sampling conducted during the RI/FS concluded that site groundwater had not impacted Flathead Lake. These results suggest that existing groundwater quality in the source area will not be a future threat to Flathead Lake.

2.5.4 Groundwater Conceptual Model Summary

NAPL has been observed in six extraction and three injection wells within the former lagoon area and also within one extraction well (well EW-6) located to the south of the lagoon as described in Section 2.4.3. In the subsurface, DNAPL is observed in root traces and in some localized sand lenses above a depth 45 feet bgs. DNAPL is not present throughout the soil matrix and a discrete pool of DNAPL has not been encountered.

- The following are pertinent information regarding the hydrogeologic conditions at the site:
- Groundwater flow occurs under water table conditions in the low permeability (2.11×10^{-5} to 3.1×10^{-4} cm/sec) fine-grained, sandy to clayey silt surficial aquifer.
- Groundwater in the surficial aquifer in the site vicinity is not used as a potable source due to low yield, high iron and availability of a municipal water supply.

- Within the surficial aquifer, groundwater flow occurs predominantly through interbedded sand lenses, however, since the sand lenses are thin and discontinuous, the groundwater flow paths are not uniform, but rather short and tenuous.
- The surficial aquifer grades downward into silty clay with no sand lenses from approximately 65 to 100 feet, below which lies bedrock. DNAPL was not observed in sand lenses occurring at depths greater than about 45 feet bgs.
- Recharge to the surficial aquifer occurs via infiltration of precipitation and recharge from Flathead Lake during high lake levels.
- The net groundwater flow direction across the site is generally to the east with the ultimate discharge point being Flathead Lake.

The contaminants present at the site are largely hydrophobic, meaning that they are fairly insoluble in water and tend to sorb to soil particles. Fate and transport modeling of the most mobile DNAPL constituent (naphthalene), indicates that the presence of DNAPL and dissolved constituents within the treatment area does not present a significant threat to the water quality of the local municipal water supply or Flathead Lake.

3 Aquifer Restoration Program

This section describes the groundwater remedial activities performed at the Somers site to date. Operational data from the Phase I groundwater treatment system is reviewed and used to assess the performance of the system in terms of its ability to meet remedial objectives.

3.1 Groundwater Remedial Action - Groundwater Treatment System

This subsection reviews the operational data and assesses the performance of the Phase I groundwater treatment system in terms of its ability to meet the remedial objectives established in the Phase I Remedial Design. These objectives were: 1) to remove and control the most heavily impacted groundwater; and 2) to obtain field-scale data on the effectiveness of in-situ biological treatment for use in the Phase II design. A description of the Phase I system is provided first, followed by a discussion of system performance, and the progress of the system towards the remedial goal of restoring the surficial aquifer.

3.1.1 Description of the Phase I System

Implementation of the Somers groundwater remedy began in 1993 with completion of the Phase I Remedial Design (RD), installation of six extraction and 14 injection wells, and construction of facilities to treat and enrich extracted groundwater. Startup of the Phase I groundwater treatment system was initiated in the spring of 1994¹⁰. This system is currently operating at the site.

Water processed through the treatment system is discharged either to the injection wells, the retention pond, or the infiltration trench¹¹. The location of the discharge of the treated water is dependent on the available volume in the retention pond and the ability to inject water in the well field. Discharge to the injection wells is limited by the aquifer formation and a high water table, which typically occurs sometime from February through July each year. During the summer months, the retention pond receives a majority of the treated water and it is used to irrigate the LTU. During the winter months when the LTU is not in operation, the retention pond is not used and treated water is discharged to the infiltration trench located to the southwest of the LTU and to the injection wells.

¹⁰ Construction details and as-builts are presented in the Final Construction Report for Phase I of the Groundwater Remedial Action, Burlington Northern Tie Treating Plant, Somers, Montana, "As-Built Construction Document" (RETEC, 1994).

¹¹ Prior to startup of the infiltration trench, some treated water was discharged to the local POTW.

3.1.2 Well Field Operations

The Phase I groundwater system at Somers has been in operation since May 1994. Routine operation of the Phase I well field system began in January 1995. Well field monitoring includes documentation of extraction and injection rates and collection of groundwater elevation data. Extraction rates have been compiled on a per-well basis since April 1996. Prior to this, only total groundwater flow into the system was recorded, in accordance with the original system specifications. Data collected from January 1994 through August 1999 are presented in this section.

Groundwater Extraction and Injection Rates

The groundwater extraction and injection rates achieved with the Phase I system are lower than the anticipated rates based on the Phase I RD. The extraction rate data collected for each well and for the Phase I system as a whole are illustrated on Figure 3-1 and are summarized in Table 3-1.

Table 3-1 Summary of Extraction Rate Data

Year	Average Extraction Rate (gpd)						Total
	EW-1	EW-2	EW-3	EW-4	EW-5	EW-6	
1994	—	—	—	—	—	—	703
1995	—	—	—	—	—	—	2,107
1996	320	293	448	287	592	1,402	3,342
1997	468	468	535	296	622	1,093	3,482
1998	625	280	484	542	849	1,764	4,544
1999	636	319	435	307	507	2,568	4,772
2000	430	221	298	212	350	1,776	3,288

Notes: "—" - Separate extraction rates were not measured for each well until April 1996.
gpd - gallons per day

Extraction rates from 1995 through 1999 are higher than the 1994 rate due to technical difficulties during startup. These rates have continued to increase gradually each year due to the addition of injection wells to the system. Extraction wells EW-1 through EW-5 each account for between 8 and 16 percent of the total volume of groundwater extracted at Somers, while well EW-6 accounts for approximately 40 percent of the total flow. A graph of the extraction performance of individual wells over time is provided on Figure 3-2. To date, no consistent seasonal fluctuations in extraction performance have been observed. Changes in extraction rates are primarily due to modifications in pump performance and the addition of injection wells. Nine of the 14 injection wells installed were used for injection from 1994 through 1997—the other five wells contained NAPL during that period and were pumped periodically until NAPL was no longer observed in the wells.

By the 1998 operating season, 12 injection wells (IW-1, IW-2, IW-3, IW-4, IW-5, IW-8, IW-9, IW-10, IW-11, IW-12, IW-13 and IW-14) were used for reinjection. Historically, product has been observed in the remaining two injection wells (IW6 and IW-7) and therefore they have not been used for injection purposes.

Injection rates ranged from approximately 158 to 679 gallons per day (gpd) on an annual basis (Table 3-2). The 1995 injection rate of 161 gpd was primarily attributed to difficulties in the operation of the injection system. During 1996, system operations were streamlined and a constant reinjection rate of 679 gpd was achieved. Reinsertion of treated water has been hampered from 1997 through 1999 by a high water table which makes it difficult to return treated water to the subsurface through injection wells for up to 6 months of the year (i.e., February through July). In the spring of 1999, the water table dropped resulting in increased injection rates of 200 to 300 gpd.

Table 3-2 Summary of Injection Rate Data

Year	Injection Rate (gpd)
1995	161
1996	679
1997	160
1998	158
1999	163

A graph showing total water extracted in comparison with total water injected is provided as Figure 3-3. To date, the amount of water that can be reinjected into the subsurface through the well field injection wells represents only 9 percent of the total volume extracted. It is important to note that circulation of water through the injection wells was a key component of the groundwater remedy to promote in-situ biodegradation of dissolved contaminants.

Groundwater Elevation Data

Groundwater elevation data was collected monthly throughout 1996, and then quarterly thereafter. Well field and site-wide groundwater elevations are measured quarterly. Potentiometric surface maps were generated using the data to assess the impact of the Phase I system on groundwater flow direction and gradients.

Figure 3-4 presents a typical potentiometric surface map of the study area prior to initiation of the Phase I system operations (March 1994), as well as one map for each subsequent year to date. The effects of drawdown from the extraction wells in the treatment system are apparent through comparison of these maps. For example, post-1994 maps show the direction of groundwater

flow toward the center of the CERCLA lagoon area, and potentiometric surface contours wrap around or are completely closed around the CERCLA lagoon area, indicating drawdown. Changes in groundwater flow direction are restricted to areas immediately adjacent to and downgradient of the recovery wells. A low is observed in the groundwater surface over an area of approximately 100,000 to 110,000 square feet (approximately 2.3 to 2.5 acres). This groundwater low may vary in size each year, but has been consistently observed since September 1994. Despite lower than predicted groundwater extraction rates, groundwater elevation data indicate the Phase I system has a large area of influence. This is expected due to the very low hydraulic conductivity of the site soils and the fact that upon dewatering, or drawdown, water infiltrates the area of influence very slowly (i.e., equal to the extractions).

Groundwater Flow Model

The well field data generated over the first 3 years of operation were used to recalibrate the MODFLOW groundwater flow model used in the RD to design the Phase I system. Details of this effort are presented in Appendix B. Reasonable simulations of hydrogeologic conditions at the site were obtained when the hydraulic conductivity values were decreased to the lower range of the reported pump test and laboratory values (i.e., 1.0 foot per day). The values used to simulate current conditions previously ranged from 0.32 to 1.64 feet per day.

The groundwater flow model uses two simplifying assumptions that are not representative of conditions at Somers: 1) wells are fully penetrating, and 2) the aquifer is homogeneous. The use of a partially penetrating well for aquifer characterization purposes (i.e., as the extraction well during a pump test) tends to overestimate actual transmissivity and conductivity values, since groundwater originating from the bedrock unscreened aquifer region is contributing flow, but is not accounted for in the equations. The assumption of homogeneity ignores the fact that the majority of pumped water may have originated in more permeable sand lenses within the soil column. Given these conditions, it is not surprising that a reduction in hydraulic conductivity values provided a more accurate representation of actual site conditions.

The hydraulic conductivity values originally used in the model were estimated with pump test methodology. In these tests, conductivity appeared to increase with distance from the pumping well. One explanation for this is that wells located closer to the extraction well were put under greater dewatering stress than wells located farther away. As the more permeable sand lenses in the aquifer surrounding the near wells were stressed in excess of their ability to deliver groundwater, the groundwater delivery from the less permeable silt horizons was then relied upon. Thus, the conductivity values calculated for the wells near the extraction network reflect the average permeability of the whole soil column to a greater degree than do those values calculated for

wells located farther away. The hydraulic conductivity values calculated for the distant wells reflect the permeability of the sand lenses.

In addition, the RDI pump tests were conducted in an area downgradient of the CERCLA lagoon, which is not in an area where most of the extraction/injection wells are installed. The area where the pump tests were performed may have a higher hydraulic conductivity than that observed in the CERCLA lagoon area due to the heterogeneity inherent to discontinuous and fine-grained interbedded silt, sand and clay stratigraphy.

3.1.3 Aquifer Restoration

This section examines the Phase I operations in terms of progress made towards aquifer restoration. Specifically, it presents a calculation of the mass of contaminants removed during Phase I and reviews groundwater quality data to determine whether any changes have occurred during the Phase I system operations.

Mass Removal

The mass of contaminant removed from the subsurface by the Phase I treatment system was estimated using information on the quantity and quality of extracted groundwater treated at the plant. For each batch treated by the Phase I system, measurements of the volume of water treated and influent/effluent water quality were collected. These measurements were used to estimate the total mass of contaminant removed as follows:

$$\text{Mass Contaminant Removed} = \text{Volume Water Treated} (\text{Concentration}_{\text{influent}} - \text{Concentration}_{\text{effluent}})$$

In early 1996 (March through May) and early 1997 (February through May), a total of approximately 3,100,000 gallons of accumulated water from snowmelt was pumped from the LTU and treated through the system in addition to extracted groundwater. During these periods, contaminant measurements were collected from the combined influent of extracted groundwater and water pumped from the LTU. To compensate for this, a uniform average influent concentration from preceding (non-snowmelt) batches was used to calculate mass removal for material recovered from the subsurface. To eliminate water volume inputs from the LTU, the volume of groundwater extracted was calculated using data from the treatment system process control. A summary of the mass of contaminant removed through the Phase I system on an annual basis is provided in Table 3-3.

Table 3-3 Mass of Contaminant Removed Using the Phase I Treatment System

Year	Volume of Groundwater Treated (gallons)	Mass of Contaminant Removed (pounds)		
		Naphthalene	Total PAH	Total SVOC
1994	179,374	10	12	16
1995	769,096	51	59	257
1996	2,248,227	155	184	409
1997	1,423,129	150	189	222
1998	2,212,730	287	422	484
1999	1,217,985	201	317	378
2000	1,173,807	267	257	412
Total	9,224,348	1,117	1,757	2,212

Over the 6-year period that the Phase I system has been consistently operational, approximately 2,212 pounds of semivolatile organics have been recovered and treated. This amount represents 2 percent of the total mass of PAHs estimated to reside in the subsurface (Section 2.4). The total mass of semivolatiles removed consisted primarily of PAH and phenolic compounds. Since operation startup, approximately 1,757 pounds of dissolved total PAHs were removed, of which approximately 1,117 pounds were dissolved naphthalene.

Due to operational modifications, a consistent rate of removal was achieved in January 1995. The apparent increases in system performance observed in 1996 can be partially attributed to the increased injection rate (679 gallons per day [gpd]) and higher than normal precipitation inputs from fall rain and snow. The apparent increase in mass removal in 1998 is most likely the result of injecting clean water into well IW-8 which previously contained NAPL, and higher than normal precipitation.

Treatment Area Groundwater Quality

Groundwater quality has been measured in several monitoring wells located within the area of influence of the Phase I treatment system. In addition, the quality of the extracted groundwater has been monitored through the treatment system. This information provides a basis from which to determine whether the Phase I system has impacted groundwater quality overall.

Prior to the initiation of system operations, wells EW-1 through EW-6, and wells IW-6, IW-7, and IW-8 all contained NAPL. Total PAH concentrations

in the dissolved phase ranged from 0.002 mg/L in well MW-93-2D to 3.9 mg/L in MW-93-2S in August 1994. Following operation of the system for approximately 5 years, NAPL is present in five of the extraction wells, but is no longer present in wells EW-6, IW-6, IW-7 and IW-8. Figure 3-5 shows the changes in NAPL occurrence over time in extraction and injection wells. Dissolved constituent concentrations in wells MW-93-2D and MW-93-2S now range from 0.503 to 2.91 mg/L, indicating little progress in the reduction of dissolved contaminants has been achieved since startup of the system and processing of 8 million gallons of extracted groundwater. Groundwater quality in wells outside the well field also remains unchanged.

The quality of water processed through the treatment system has not changed appreciably over time (Figure 2-5)¹². However, greater variability in total semivolatile influent concentrations is observed compared to total PAHs or naphthalene. This may be indicative of reductions in the concentration of phenolic compounds such as phenol, 2-methylphenol, 4-methylphenol, and 2,4-dimethylphenol within the groundwater. These compounds are more water soluble than the majority of PAHs and are therefore more likely to be removed along with extracted groundwater. The temporary spike in semivolatile organic concentrations in 1998 may be attributed to bringing injection well IW-8 online. This well had previously contained free-phase NAPL, which was removed prior to bringing the well online. However, residual NAPL likely remained in the area surrounding the injection well. Circulation of water through this area may have resulted in a temporary increase in dissolved-phase contaminant concentrations.

3.2 Site-wide Groundwater Quality

A comprehensive groundwater monitoring program has been established and maintained at the Somers site. The monitoring program includes both site-wide and treatment area groundwater quality. The most recent reporting period was from May 1999 through March 2000 (ThermoRetec, 2000). Figures 3-6 through 3-9 present the most recent site-wide groundwater data. For this period, six wells exceeded total PAH target cleanup level of 40 µg/L; S-6, S-88-1, S-88-2, S-88-3, MW-93-2D, and MW-93-2S, and three wells (S-85-8a, S-85-6a, and S-85-6b) exceeded zinc drinking water standards. All of the six wells exceeding the total PAH level are sampled quarterly as part of the voluntary or treatment area networks. Well S-88-1 was not sampled during the June 1999 event, and well S-88-3 did not exceed the total PAH target cleanup level during September 1999.

Appendix E presents the analytical results of TPAH compounds in site-wide wells from June 1984 through March 2000. Since implementation of the selected groundwater remedy, the following wells have had observed TPAH

¹² Note: influent water quality for the periods from March through May 1996 and January through May 1997 represents a combined flow of extracted groundwater and LTU snowmelt water.

concentrations greater than the target level: S-88-1, S-88-2, S-88-3, MW-93-2S and MW-93-2D, all located in the treatment area and well S-6, located north of the treatment area.

Figure 3-10 presents historical data that indicates prior to March 1998, all reported TPAH concentrations in well S-6 were below detection limits. Since March 1998, naphthalene has been the only PAH constituent observed in well S-6 (Table E-2). Due to the recent anomalous observed concentrations of naphthalene in well S-6, well S-91-2 was sampled in April 2000 (Table E-3). Well S-91-2 is located downgradient from well S-6 (Figure 3-9) and has a similar screened interval. All observed concentrations were below the target levels for total PAHs and total phenols. It is important to note that upgradient well S-6 has naphthalene concentrations two orders of magnitude higher than well S-91-2, and the primary observed compounds in the down gradient well are phenolics, when well S-6 has historically been non-detect for phenols. Historical zinc concentrations (Figures 3-6 through 3-9) demonstrate a variation of zinc concentrations in wells across the site with no apparent correlation to a potential source area or temporal trends.

Figure 3-11 shows the treatment area wells and TPAH concentrations over time. The distribution of dissolved PAHs in the CERCLA lagoon area coincides with areas of residual source in soil and root traces and the direction of groundwater flow. Figures 3-12 and 3-13, show time series total PAH data from wells S-88-1, S-88-2, S-88-3, MW-93-2S and MW-93-2D. Review of groundwater data indicate that total PAH concentrations vary little from observed concentrations prior to treatment startup. To support this concept, analytical data from the wells with total PAH greater than the target level were statistically reviewed and evaluated for seasonality and trends.

3.2.1 Statistical Analysis

Historical TPAH concentrations from June 1984 through March 2000 (Appendix E) were used to conduct the statistical analyses to determine if the data represents trends in groundwater quality. The appropriate selection of monitoring well data is outlined in the *Protocol for the Statistical Analysis of Groundwater Data* (RETEC, 1998 located in Appendix D).

The data for wells S-6, S-88-2, S-88-3, MW-93-2S, and MW-93-2D were tested for seasonality using the Kruskal-Wallis test (Gilbert, 1987) at the 5 percent significance level. The Kruskal-Wallis test is a non-parametric test that determines differences in groupings of data or, in other words, whether there is a consistent change in concentrations within a year of data. This would indicate other factors (i.e., groundwater flow direction changes) that could mask any long-term trends in groundwater PAH concentrations. This test is a standard application to ensure that there are no other factors that will negatively influence the trend test.

The existence of a significant trend was determined using the Mann-Kendall trend analysis (Gilbert, 1987), which is a non-parametric procedure that is used to estimate trend when seasonality does not exist. Results are reported at the 5 percent level of significance (Appendix D). A non-parametric test, as opposed to a parametric regression analysis, was used due to the large number of non-detects and the sporadic nature of the data sets. The Mann-Kendall test looks for trends in ranking of the data, rather than in the absolute value for the data. The Sen's Slope Estimator (Gilbert, 1987) was used to determine the rate of change over time of TPAH concentrations in each well. The slope of the concentrations is only valid if the Mann-Kendall test was significant.

Well S-6

Well S-6 was non-detect for TPAH throughout the historical period; however, there were detections of TPAH from March 1998 through March 2000. The detection in March 1998 was 3 µg/L, increasing to 570 µg/L in September 1998. Detections between September 1998 and March 2000 ranged from 320 to 600 µg/L. The data from March 1998 to March 2000 was analyzed statistically.

The Kruskal-Wallis seasonality test indicated no seasonality, however, there were not enough seasons of data to enable an accurate test. The Mann-Kendall trend test indicated no significant trend. The sudden increase in TPAH during the September 1998 sampling period, and subsequent high TPAH values, are unexplained. This well has been monitored further to assess any trend in the data over time. The data has been presented in the annual reports and a significant downward trend has been observed.

Wells S-88-2 and S-88-3

The S-88-1, S-88-2 and S-88-3 data consisted of a cluster of analyses conducted in the summer of 1988, followed by semi-annual data collected from August 1996 through March 2000. The S-88-1 data is sporadic, with results reported for August 1996, March 1998, September 1998, and March 1999; however, there were detections at high concentrations (6,901 to 12,381 µg/L) in September and December 1999 and March 2000. This data for well S-88-1 is not sufficient to conduct a statistical analysis, and more data will be required to proceed. Wells S-88-2 and S-88-3 contained more complete data, and were analyzed statistically.

The Kruskal-Wallis seasonality test indicated no seasonal effects of TPAH concentrations for either of the two wells. The Mann-Kendall trend test indicated no significant trend at the 5 percent level for well S-88-2, but a significant downward trend of 132 µg TPAH/L per year for well S-88-3. A graphical presentation of the data indicates that the TPAH concentrations are decreasing in both S-88-2 and S-88-3 (Figure 3-11). Further sampling results are needed to better assess the data trend.

Wells MW-93-2S and MW-93-2D

The MW-93-2S and MW-93-2D data consisted of quarterly analyses spanning the historical period from August 1994 through March 2000, and were analyzed statistically. The historical data used for the statistical analyses are presented Figure 3-12.

The Kruskal-Wallis seasonality test indicated no seasonality at the 5 percent significance level for either of the two wells. The Mann-Kendall trend test indicated no significant trend for well MW-93-2S, but an increase in TPAH for well MW-93-2D. The significant increase in TPAH in well MW-93-2D appears to be due to the abnormally high TPAH value reported in June 1999 (2,711 µg/L). Since this time, the TPAH concentrations in both wells have dropped to within their normal ranges for these wells. Therefore, the statistical increase in TPAH concentrations in well MW-93-2D is considered to be an anomaly, as it appears that there is no apparent trend in this well.

3.2.2 Groundwater Quality Conclusions

Five monitoring wells (S-6, S-88-2, S-88-3, MW-93-2S, and MW-93-2D) were tested for seasonality and trend in TPAH concentrations. There was evidence of a trend in TPAH concentrations in wells S-88-3 and MW-93-2D, but there was no evidence of a trend in any of the other wells. There was a statistically significant downward trend in TPAH in well S-88-3, and a statistically significant upward trend in well MW-93-2D. The downward trend in well S-88-3 is indicative of TPAH concentrations in both of the S-88 wells that were analyzed. The trend in well MW-93-2D appears to be a result of an unusually high naphthalene value in June 1999. The TPAH concentrations in this well have decreased to within the normal historical range since that sampling period. Historical zinc concentrations demonstrate a variation of zinc concentrations in wells across the site with no apparent correlation to a potential source area or temporal trends.

In summary, review of historical groundwater monitoring data indicate that, while there is a range of concentrations observed in the monitor wells tested, the dissolved PAH plume has shown no statistically significant change in groundwater concentrations in treatment area wells since treatment system startup.

4 Aquifer Restoration Potential

This section evaluates the current Phase I groundwater remediation objectives and discusses the operational performance of the treatment system and its effectiveness in recovering DNAPL at the Somers site. Factors effecting groundwater restoration are discussed in terms of hydrogeologic conditions and contaminant related factors that affect DNAPL recovery. An engineering evaluation of alternate remedial technologies to the restoration of the Somers aquifer is also presented.

4.1 Groundwater Remedy Remedial Objectives

In December 1993, EPA granted conditional approval of the *Final Design Report for Phase I of the Groundwater Remedial Action at the Burlington Northern Tie Treating Plant*, Somers, Montana (RETEC, 1993). EPA approval was conditional upon submittal of additional detail on the design basis for Phase II of the remedy. That detail, provided in an addenda dated March 10, 1994, included the following discussion:

If the Phase I data indicate that it is not technically feasible to achieve the ROD cleanup levels within 50 years, then several options will be examined with EPA. One such option could be to modify the project goals in terms of the desired groundwater cleanup levels and/or restoration time frame. Any such modification would need to be shown to be protective of human health and the environment. Applicable EPA guidance including the recently published recommendations on managing and remediating sites contaminated with DNAPLs (OSWER Directive 9234.2-25, September 1993) would be followed to support any such determination.

In May 1998, BNSF submitted the *Final Phase II Groundwater Remedy Remedial Design* (RETEC, 1998) document to EPA. That document presented several findings of the Phase I system operation indicating that due to characteristics of site geology, hydrogeology and the contaminant present it would not be technically feasible to achieve the ROD cleanup levels. Data collected on the performance of the Phase I system since the publication of that report also support these findings, which are as follows:

- Extremely low extraction and injection rates have been achieved during the first six years of Phase I operation;
- *Aquifer Restoration Potential* Limited removal of the PAHs present in the subsurface (less than 2 percent) has been achieved during the first six years of operation; and
- No discernable site-wide groundwater quality improvements have been achieved.

Further discussion of the effectiveness of the Phase I groundwater remedy at meeting the remedial goals specified in the ROD is provided below. This

section is followed by an engineering evaluation of the other remedial alternatives potentially applicable to the site and evaluated in the Final Phase II Groundwater Remedy Remedial Design. This section concludes with BNSF's recommended Phase II groundwater remedial action.

4.2 Operational Performance of Groundwater Remedy

The Phase I groundwater treatment system has been in operation since May 1994. The groundwater extraction and injection rates achieved with the Phase I system are lower than the anticipated rates based on the Phase I RD. The following list summarizes the operational performance of the Phase I groundwater treatment remedy:

- An overall extraction rate of 3 gpm has been achieved with the Phase I treatment system. This value is approximately 25 percent of the value anticipated in the Phase I design.
- Approximately 2,212 pounds of dissolved-phase constituents have been removed during the 6-year operation of the Phase I system.
- The total mass of contaminants removed during six years of Phase I treatment system operation represents 2 percent of the total contaminant loading estimated to reside in the subsurface.
- The maximum annual injection rate achieved at the site is approximately 0.5 gpm. To date, only 9 percent of the water treated at the site has been reinjected in the well field. The other 91 percent of this water has been used to irrigate the LTU or has been discharged to the infiltration trench. Discharge to the local POTW occurred in 1995 and was discontinued due to lack of treatment capacity.
- Operation of the Phase I system has resulted in the removal of free-phase NAPL from four out of nine NAPL-bearing wells in the treatment area (wells EW-6, IW-6, IW-7 and IW-8). In general, dissolved-phase constituent concentrations in the treatment area and surrounding monitoring wells have shown no statistically significant change. Concentrations of phenolics compounds in the treatment system influent have decreased. Influent concentrations of naphthalene and total PAHs have been variable with no apparent trend.

Soil column testing was conducted during the RDI and reported in the 1991 RDI Technical report (RETEC, 1991). The results of the column testing led to an estimation of treatment to reach the ROD clean-up levels. The RDI estimated that a well spacing of 85 feet and a pore volume (PV) exchange of

850 pore values) (PVs) of nutrient- and oxygen-enriched water would need to be transported through the subsurface to achieve the ROD cleanup levels. The revisions to cleanup levels by EPA in the 1998 ESD¹³ (e.g., from 0.030 to 0.047 µg/L carcinogenic PAH) did not substantially change this pore volume estimate.

During the 6 years of Phase I system operations, 9.2 million gallons of extracted groundwater were processed through the groundwater treatment system. The volume of one PV in the Phase I treatment area is estimated to be 3 million gallons¹⁴. Therefore, the extraction of 1.6 million gallons of groundwater per year is equivalent to the exchange of 0.53 PV per year. Viewed from another perspective, the existing Phase I system provides for treatment of 1 PV in approximately 2 years. At this rate, approximately 1,700 years of Phase I operation would be required to reach ROD levels through the exchange of 850 PVs.

Therefore, the operational data indicate that the Phase I system is not able to meet the remedial objectives established in the ROD. The Phase I system was adequately designed to treat contaminants at the Somers site, but is not operating at optimum capacity due to hydrogeological factors and contaminant-related factors encountered at the site. Specifically, the low permeability of the aquifer limits dissolved-phase DNAPL recovery using currently available remedial methods. The primary impediment to restoration of the aquifer is the inability to extract contaminants or circulate nutrient-enriched water effectively. The inability to effectively remove DNAPL at the Somers site is primarily due to the properties of DNAPL, but is not independent of hydrogeological conditions. DNAPLs are often particularly difficult to locate and remove from the subsurface due to their ability to sink through the water table and penetrate deeper portions of aquifers (EPA, 1993). Furthermore, the contaminants present at the site are largely hydrophobic, meaning that they are fairly insoluble in water and tend to sorb to soil particles.

Review of the Phase I operations data indicates it is not technically feasible to achieve full aquifer restoration (as defined in the 1989 ROD). An evaluation of other remedial options that may be able to achieve the groundwater restoration goals specified in the ROD was presented in the Final Phase II Groundwater Remedy Remedial Design and summarized in the next section.

4.3 Alternate Groundwater Remedies

A review of alternative groundwater cleanup technologies has been presented in previous Somers site work (RETEC, 1998) and is summarized below. The Final Phase II Groundwater Remedy Remedial Design identified and

¹³ Refer to Section 5.1 for more discussion of EPA's 5-year review.

¹⁴ Based on the potentiometric surface data, an assumed porosity of 0.25 and a saturated thickness of 55 feet

evaluated the potential effectiveness and application of six remedial alternatives that were discussed as being potentially applicable to Phase II of the Somers groundwater remedy. Institutional controls as required by the ROD would be implemented for each alternative. These controls may not be the same for each alternative; rather they would vary depending on the time frame land area needed for remediation. The evaluation included an analysis of the restoration time frames that might be associated with each alternative. The ROD presented a 50-year time period for groundwater restoration as a project goal. The Phase II alternatives were evaluated in terms of their expected performance in a 100-year time period. The following six alternatives were evaluated as alternate groundwater remedies:

Alternative 1 - Continued Phase I Operations. Under this alternative, operation of the Phase I system would continue until ROD levels were met. No major expansion or modifications would be undertaken; routine maintenance and monitoring would continue. As discussed above, review of Phase I operations indicates it is not technically feasible to achieve full aquifer restoration.

Alternative 2 - Expanded Phase I Operations. In this alternative, the Phase I system would be expanded through the installation of additional extraction and injection wells. Enough wells would be added to attempt to meet the target extraction rate of 20 pore volumes (PVs) per year. With the current system of six extraction wells, an average extraction rate of 0.5 PVs per year has been achieved. To meet the 20 PVs per year goal, the system would have to be expanded by a factor of 40 (i.e., 20 PVs / 0.5 PVs). This would require the installation of 234 additional extraction wells on 25-foot centers in the treatment area. This system expansion would also require the installation of additional injection wells and an infiltration trench to accommodate the increased volume (if realized) of treated excess water.

Theoretically, expansion of the Phase I system in this manner could increase the number of PVs extracted per year and possibly meet the ROD goals within a 50-year period. Phase I data indicate that the aquifer is not capable of yielding enough water to meet the required extraction rate, regardless of the number of wells; therefore, a 100-year time period was used for cost estimating. Therefore, a significant uncertainty remains regarding the ability of this alternative to meet groundwater remediation goals.

Alternative 3 - Modified Phase I Operations with Product Recovery Focus. Under this alternative, the Phase I system would be modified to focus on the area of DNAPL occurrence, i.e., the CERCLA lagoon. Well EW-6 would be shut down and wells EW-1 through EW-5 would be maintained. Each of these wells would be equipped with a low-flow pump and operated on a timer set to minimize water extraction and maximize product recovery. Further enhancement of DNAPL recovery might be

accomplished through innovative technologies such as electro-osmosis. However, a measurable thickness of DNAPL has not been observed in wells at the site, nor has accumulated in the primary settling and equalization tank of the groundwater treatment system. This would imply that the amount of recoverable DNAPL is negligible. Based on experience at other sites, the initial period of extraction is when the most effective product recovery occurs; product recovery rates often decline sharply with time. With this in mind, continued pumping in the treatment area would be expected to generate even less product than has been recovered on site to date. Residual creosote would remain following removal of free phase product and continue to be a source of groundwater contamination. The time frame for this alternative to meet remediation goals is estimated to be the same or greater than the 1,700 years of continued Phase I operations.

It was determined that the potential effectiveness of DNAPL recovery enhancement through electro-osmosis would be limited based on the contaminant distribution at the Somers site. The benefits of electro-osmosis are limited to fine-grained soil; however at the Somers site, DNAPL tends to occur within coarser-grained sand lenses and root traces.

Alternative 4 - Modified Phase I Operations with Containment Focus. This alternative is, in effect, the opposite of the previous alternative. Well EW-6 would be maintained, well CP-1 would be brought online and wells EW-1 through EW-5 would be shut down. Well EW-6 and a new recovery well located to the west of well EW-6 would be used to provide containment of the area of concern. Phase I operations have shown that hydraulic containment can be effectively implemented at the Somers site. The overall benefits of containment may be minimal, however. The low rates of groundwater transport that naturally occur at the site already provide for effective containment. This was demonstrated by the fate and transport modeling (Section 2.5.3 and Appendix C). The incremental benefit associated with groundwater pumping was shown to be minimal in the Final Phase II Groundwater Remedy Remedial Design. A flushing efficiency analysis indicates that the sparingly soluble carcinogenic PAHs are not readily removed by pumping, since approximately 99 percent of the benzo(a)pyrene remains after 22 years (N=50) of flushing. Containment pumping downgradient of the treatment area will not greatly enhance treatment in the source area.

Alternative 5 - Monitored Natural Attenuation. All the recovery and injection wells would be shut down in this option. Groundwater monitoring would be conducted to ensure that the natural processes of adsorption, dispersion, and degradation are effectively containing the contaminants. Site hydrogeology provides contaminant containment, however groundwater remediation levels would not be met within a measurable time frame.

Alternative 6 - Institutional Controls. As above, all the recovery and injection wells would be shut down. In this case, however, groundwater monitoring would occur to document the long-term stability of the groundwater plume and designation of a Controlled Groundwater Use Area would be used to prevent extraction of contaminated groundwater for purposes other than monitoring. Contaminant containment is a natural artifact of site hydrogeology and groundwater remediation levels would not be met within a measurable time frame.

Each of these alternatives is described in more detail below and evaluated in terms of its effectiveness, the resources needed to implement the alternative and capital and operating and maintenance (O&M) costs associated with each alternative.

4.3.1 Continued Phase I Operations

Description

This alternative makes use of all existing recovery and injection wells and of the existing groundwater treatment and enrichment systems. The existing infiltration trench may need to be expanded to accommodate water that is currently used as irrigation water on the LTU; LTU soil remediation goals have been met and the LTU will be closed in 2001.

Effectiveness

Although the data collected to date from the Phase I system suggest that it is not an effective means of aquifer restoration, the Phase I system is providing effective hydraulic containment and, with time, may provide for some in-situ treatment. The Phase I design estimated that 850 PVs of nutrient- and oxygen-enriched water would need to be transported through the subsurface systems to achieve the ROD cleanup levels. The revisions to cleanup levels proposed by EPA in the 5-year review (e.g., from 0.030 to 0.047 $\mu\text{g/L}$ carcinogenic PAH) would not substantially change this pore volume estimate.

During the first 6 years of operations, 9.2 million gallons of extracted groundwater were processed through the groundwater treatment system. The volume of one PV in the Phase I treatment area is estimated to be 3 million gallons¹⁵. Therefore, the extraction of an average 1.6 million gallons of groundwater per year is equivalent to the exchange of 0.53 PV per year. Viewed from another perspective, the existing Phase I system provides for treatment of 1 PV every 2 years. At this rate, approximately 1,700 years of Phase I operation would be required to reach ROD levels through the exchange of 850 PVs. One hundred years of operation would result in the exchange of 53 PVs. Based on the RD findings, the effect of exchanging 53

¹⁵Based on the potentiometric surface data, an assumed porosity of 0.25 and a saturated thickness of 55 feet.

PVs would be to reduce total PAH concentration by less than 12 percent, which is expected to have a minimal impact on groundwater quality.

Implementability

This is a very implementable alternative; the systems required are fully constructed and only need to be maintained and operated. The systems were not, however, designed for a life of 1,700 years and would need to be replaced many times during this period. The ROD would need to be modified to reflect the fact that the system is expected to operate indefinitely, rather than for 50 years.

Cost

The labor and other direct costs needed to operate and monitor the Phase I groundwater remedy are currently about \$250,000 per year. An economy of scale is currently realized because Phase I activities are conducted in conjunction with LTU operations; once LTU operations cease, the annual O&M costs will increase. A 10 percent increase would not be unreasonable and would result in annual costs of \$275,000. The present value of 100 years of O&M at \$275,000 per year with a 6 percent rate of return is \$4.4 million.

4.3.2 Expanded Phase I Operations

Description

This alternative would expand the existing system of extraction wells to meet the target extraction rate of 20 PV per year. With the current system of six extraction wells, an average exchange rate of 0.53 PVs per year has been achieved. To meet the 20 PV per year goal, the system would have to be expanded by a factor of 40 (i.e., 20 PV / 0.53 PV). This would require the installation of additional 234 extraction wells on 25-foot centers in the CERCLA lagoon area and in the area adjacent to well EW-6 located across Somers Road from the CERCLA lagoon. This system expansion would also require the installation of additional injection wells and an infiltration trench to accommodate the increased volume of treated excess water.

Effectiveness

While the expansion of the Phase I treatment system to the level described above is technically possible, the corresponding increase in the number of PVs extracted per year may not be attainable and the ROD goals for groundwater treatment may not be met within the 50-year period defined in the ROD. Data suggest that the aquifer may not be capable of yielding enough water to meet the required extraction rate. Actual rates of extraction and re-injection in Phase I wells are much lower than those estimated by the Phase I design (Section 3.1). Therefore, a significant uncertainty remains regarding the ability of this system to meet the ROD defined goal in a 50-year time period.

Operating costs were calculated for a 100-year time period due to this uncertainty.

Implementability

A period of approximately 1 year would be required to install the additional extraction wells, associated pumps and piping, and the new injection wells and trench. Groundwater modeling would be used to locate and size the extraction and injection wells. The existing water treatment system is adequate to treat the estimated 60 gpm that would require treatment. Maintenance of the extraction and injection well network would be difficult. Phase I operations have shown that the fine-grained nature of the aquifer sediments quickly fouls pumps and piping.

Cost

Capital costs required to expand the extraction/injection system at the site would be on the order of \$2.9 million based on costs required to install the Phase I treatment system. The labor and other direct costs needed to operate and monitor the expanded Phase I groundwater remedy would nearly double to an estimated \$500,000 per year. The present value of 100 years of O&M at \$500,000 per year with a 6 percent rate of return is \$8.3 million.

4.3.3 Modified Phase I Operations with Product Recovery Focus

Description

This alternative makes use of some of the existing Phase I components but modifies other components to focus on and improve the recovery of DNAPL. Six extraction and three injection wells within the area of the former CERCLA lagoon have contained DNAPL accumulations (refer to Figure 2-4). Each of these wells would be equipped with a low-flow pump and operated on a timer set to minimize water extraction and maximize product recovery. It is expected that these wells would be evacuated on a daily basis although the frequency would be selected on the basis of recovery data.

Use of hot water flushing to promote recovery of DNAPL was examined in the RD and found to be of limited use at Somers. Literature and vendor data were examined to see if new technologies had been developed since the completion of the RD that could be used to enhance product recovery at Somers. One potentially promising technology examined for use at Somers is electro-osmosis. This is an emerging technology under development for remediation of low-permeability soil. The technique involves inducing aqueous fluid flow to an extraction well at rates that exceed Darcy flow. This is accomplished by establishing an electrical field across the impacted portion of the subsurface formation. The electrical field mobilizes pore water that is otherwise bound to the soil by electrostatic forces. The initial focus of the

technology development efforts was removal of dissolved-phase contamination from fine-grained soil. Interest in electro-osmotic DNAPL recovery may expand the potential applications of the technology. However, there have been no field applications to date where electro-osmosis has been used for NAPL recovery (or dissolved-phase PAH remediation).

Effectiveness

A measurable thickness of DNAPL has not accumulated in the primary settling and equalization tank; however, sorbed DNAPL constituents may adhere to silt particles that have collected in the tank.¹⁶ As a result, the amount of DNAPL that manual and automated recovery during Phase I has generated is currently being evaluated through laboratory analysis of silt samples. Based on experience at other sites, the initial period of extraction is when the most effective product recovery occurs; product recovery rates often decline sharply with time. With this in mind, continued operation of Phase I without modifications would be expected to generate even less product than have been recovered on silt to date. It is expected that all recoverable DNAPL would be removed in much less than 50 years; a 10-year period is a reasonable assumption. Residual DNAPL would remain and would continue to be a source of groundwater contamination.

The use of electro-osmosis to remove additional DNAPL was examined in terms of its potential to increase the effectiveness of DNAPL recovery. The potential benefits of electro-osmosis are confined to fine-grained soil where the electro-osmotic flow potential is much greater than the Darcy flow potential. The opposite is true of coarse-grained or high-permeability soil where the Darcy flow exceeds the electro-osmotic flow potential. At Somers, the DNAPL tends to occur primarily within coarser-grained sand lenses and root traces; little is present within the finer-grained silts and clays. This limits the potential effectiveness of this enhancement technology for Somers.

Implementability

Recovery and injection wells south of Somers road with no observed DNAPL would be abandoned. The injection wells in the CERCLA lagoon that contain DNAPL can be modified to be recovery wells; electrical lines, piping and controls need to be added. The existing treatment system would continue to be operated in a batch mode. The frequency of operation would be even less because of the lower extraction rates and the focus on product recovery. Use of electro-osmosis as an enhancement to DNAPL recovery is an emerging technology and is not field-proven. Electro-osmosis is therefore not considered to be implementable since extensive pilot testing would be

¹⁶ DNAPL in wells primarily occurs sorbed to silt present in the water column. On purging of these wells, water removed is typically brownish-yellow and contains less than 5 percent of a fine dark brown/black silt. The water surface typically contains a slight sheen and has a creosote odor. Small (1- to 2-mm diameter) droplets of creosote product may be visible on the sides of bailer. A separate DNAPL product phase is not observed.

required. The ROD would need to be modified to reflect the change from aquifer restoration to product recovery.

Cost

No cost estimate can be reliably developed for electro-osmosis because of its undemonstrated status. The following costs consider only conventional recovery using existing wells.

Capital costs to abandon wells south of Somers road and to reconstruct three injection wells as recovery wells are estimated to be \$130,000 (\$5,000 per well to abandon 12 wells, \$20,000 per well to reconstruct three injection wells, \$2,500 per well to revise the controls on four recovery wells). Annual O&M costs would be less than the projected in the first alternative because of the lower flow rate and corresponding lower material (carbon) usage, and because of the reduced monitoring that would be required. O&M costs would be about 30 percent less than costs for continued Phase I operation and is estimated at an annual cost of \$190,000 per year. It is assumed that all recoverable DNAPL could be collected within a 10-year period; the present value cost of the annual O&M is therefore \$1.4 million. Total (capital and O&M costs) are estimated to be \$1.5 million.

4.3.4 Modified Phase I Operations with Containment Focus

Description

The existing Phase I system provides a level of hydraulic containment that could be maintained to further reduce the potential for contaminant migration. Hydraulic containment is a common technique for preventing contaminants from migrating with groundwater flow towards downgradient receptors. This technology involves the capture of groundwater within a predefined area by pumping from a series of wells and/or trenches. The recovery wells at Somers have provided effective hydraulic containment. In addition, the treatment system at Somers has effectively treated the extracted groundwater. Management of treated groundwater remains an issue at Somers and once on-site soil treatment is completed, an alternate means of disposal would be required to implement this option during winter months.

Well EW-6 and a new recovery well located to the west of well EW-6 would be used to provide containment of the area of concern. The groundwater transport model (Appendix B) was used to assess the containment that would be provided by pumping these two wells at a rate of 1 gpm. Figure 4-1 shows that the capture area encompasses the CERCLA lagoon and much of the downgradient dissolved plume.

Effectiveness

Phase I operations have shown that hydraulic containment can be effectively implemented at the Somers site. The overall benefits of that containment may be minimal, however. The low rates of groundwater transport that naturally occur at the site already provide for effective containment. This was demonstrated by the fate and transport modeling (Section 2.5 and Appendix C). The incremental benefit associated with groundwater pumping may be minimal. The flushing efficiency analysis of the fate and transport analysis (Table 4-1 and Appendix C) indicates that the sparingly soluble carcinogenic PAHs are not readily removed by pumping, since approximately 99 percent of the benzo(a)pyrene remains after 22 years (N=50) of flushing. Note also that this analysis assumes instantaneous equilibrium with each new PV of water, when in reality, equilibrium comes slowly. This analysis also assumes that all the benzo(a)pyrene is in direct contact with groundwater and ignores media heterogeneities, effective versus total porosity, rates of dissolution, etc. (Brubaker and Stroo, 1992). In reality, even less contaminant removal than predicted by the flushing analysis may occur.

Implementability

A new recovery well could be constructed and well pumps and controls are relatively easy to install. The ROD would need to be modified to reflect the change from aquifer restoration to containment. This alternative could be readily implemented.

Cost

Capital costs are for abandonment of wells in the CERCLA lagoon and installation of a new recovery well. The estimate of \$110,000 includes \$5,000 per well to abandon 18 wells and \$20,000 to install a new recovery well. Annual O&M costs would be less than continued Phase I operation because of the need to maintain fewer pumps and because of the reduce monitoring; a 30 percent reduction is estimated for an annual cost of \$190,000 per year. It is assumed that the containment would be provided for an indefinite period of time; the present value for 100 years of operation is \$3.2 million. Total (capital and O&M costs) are estimated to be \$3.3 million.

Table 4-1 Flushing Efficiency Calculations

Compound	Kd ⁽¹⁾ (cm ³ /g)	Ka ⁽²⁾ (dimensionless)	Pore-Volume Flushing Efficiency [1-1/(Ka+1)]^N Fraction of Constituents Remaining After "N" Pore Volumes of Flushing						
			N=1	N=10	N=50	N=100	N=500	N=1000	N=2000
PAHs									
Acenaphthene	0.05	0.18	0.15	0.00	0.00	0.00	0.00	0.00	0.00
Acenaphthylene	14.40	52.20	0.98	0.83	0.39	0.15	0.00	0.00	0.00
Anthracene	55.90	202.64	1.00	0.95	0.78	0.61	0.09	0.01	0.00
Fluoranthene	125.10	453.49	1.00	0.98	0.90	0.80	0.33	0.11	0.01
Fluorene	15.00	54.38	0.98	0.83	0.40	0.16	0.00	0.00	0.00
Naphthalene	1.70	6.16	0.86	0.22	0.00	0.00	0.00	0.00	0.00
Phenanthrene	15.70	56.91	0.98	0.84	0.42	0.18	0.00	0.00	0.00
Pyrene	137.10	496.99	1.00	0.98	0.90	0.82	0.37	0.13	0.02
cPAHs									
Benzo(a)anthracene	4,141	15,011	1.00	1.00	1.00	0.99	0.97	0.94	0.88
Chrysene	736	2,668	1.00	1.00	0.98	0.96	0.83	0.69	0.47
Benzo(b)fluoranthene	1,649	5,978	1.00	1.00	0.99	0.98	0.92	0.85	0.72
Benzo(k)fluoranthene	13,095	47,469	1.00	1.00	1.00	1.00	0.99	0.98	0.96
Benzo(a)pyrene	1,194	4,328	1.00	1.00	0.99	0.98	0.89	0.79	0.63
Dibenzo(a,h)anthracene	4,979	18,049	1.00	1.00	1.00	0.99	0.97	0.95	0.90
Benzo(g,h,i)perylene	23,287	84,415	1.00	1.00	1.00	1.00	0.99	0.99	0.98
Indeno(1,2,3-cd)pyrene	92,709	336,070	1.00	1.00	1.00	1.00	1.00	1.00	0.99

Notes:

1. Sorption Coefficient, $K_d = f_{oc} * K_{oc}$, where $f_{oc} = 0.003$.
2. Aquifer partitioning coefficient, $K_a = (K_d * b_d / W)$, where b_d is the soil bulk density (1.45) and W is the soil water content (0.40) (Brubaker and Stroo, 1992).

4.3.5 Monitored Natural Attenuation

Description

Under this alternative, all the recovery and injection wells would be abandoned and an extensive monitoring program would be implemented to confirm and document the fate and transport analyses presented in Section 2.5.

Effectiveness

The natural processes that affect contaminant fate and transport were introduced in Section 2.5. The effectiveness of this alternative was assessed using site-specific hydrogeologic parameters and the fate and transport equations presented in Appendix C. Transport results (Table 4-2 and Appendix C) indicate that solute velocities and travel times are extremely low for PAH compounds with high organic-carbon partitioning coefficients. Low solubility compounds such as the 5- and 6-ring PAHs (e.g., benzo(a)pyrene) have low solute velocities and high distribution coefficients. The degradation time analysis (Table 4-3 and Appendix C) suggests that the detectable concentrations of individual PAH compounds in Well 93-2S groundwater would degrade to a groundwater concentration of 1 µg/L in fewer than 7 years if a constant contaminant source were not present.

These factors indicate that the mechanisms needed to contain the contaminants exist naturally; the compounds are either highly immobile or readily degradable.

Implementability

The on-site activities needed to implement this alternative (the abandonment of recovery and injection wells, monitoring well installation and monitoring) are easy to complete. The monitoring data would need to be reviewed carefully to ensure that the project objectives are maintained. The ROD would need to be modified to reflect the change from aquifer restoration to natural attenuation.

Costs

Capital costs are for well abandonment of recovery and injection wells. It is expected that the salvage value from the treatment plant would offset these costs such that no net capital cost would be required. Annual monitoring and reporting costs are estimated to be on the order of \$100,000 per year (20 to 25 wells twice per year at \$1,200 to \$1,500 per well for sample collection, analysis and validation plus \$40,000 for reporting). Assuming a 100-year period, the present value cost of this option is \$1.6 million.

4.3.6 Institutional Controls

Description

Under this alternative, the existing recovery and injection wells would be abandoned as described in the Monitored Natural Attenuation alternative. In addition, BNSF would work with a local or state public health agency to designate the downgradient area as a "controlled groundwater use area" under the Montana Department of Natural Resources and Conservation (DNRC). Such a designation would restrict the installation of water supply wells in this area. In addition, BNSF continues to work with the other affected landowners (Sliters, Inc.) to either adopt restrictive covenants for their property or to obtain title to their property and then impose restrictive covenants on use of groundwater.

Limited groundwater monitoring would be conducted to ensure that contaminant migration does not threaten either the Somers municipal water supply aquifer or Flathead Lake.

Effectiveness

The restricted water use designation, in combination with the natural limitations of the aquifer, would be an effective means of preventing groundwater use (and the potential risks associated with ingestion of contaminants in groundwater downgradient of the site). Monitoring is an effective means of assessing contaminant migration, particularly in aquifers such as Somers with low groundwater and low solute transport velocities.

Implementability

BNSF has petitioned DNRC for a Controlled Groundwater Use Area designation. The ROD would need to be modified to reflect the reliance on institutional controls.

Cost

As above, the salvage value of the treatment plant is expected to offset the costs associated with well abandonment and obtaining the controlled groundwater use restriction. Annual monitoring and reporting costs are estimated to be on the order of \$30,000 per year (six to eight wells twice per year at \$1,200 to \$1,500 per well for sample collection, analysis and validation plus \$20,000 for reporting). Assuming a 100-year period, the present value cost of this option is \$0.5 million.

Table 4-4 summarizes each alternative in terms of its effectiveness, implementability and cost.

Table 4-2 Transport Calculations

Compound	Solubility, S ⁽¹⁾ (mg/L)	Specific Density ^(1,2) (unitless)	Rate, k ⁽³⁾ (per year)	Biodegradation Koc ⁽¹⁾ (cm ³ /g)	Kd ^(1,2) (cm ³ /g)	Retardation Factor, R (unitless)	Solute Velocity, v ⁽⁵⁾ (feet/year)
PAHs							
Acenaphthene	3.47	1.02 (90/4)	1.10	18	0.05	1.3	1.7
Acenaphthylene	3.93	0.90 (16/2)	2.19	4,786	14.4	84.3	0.03
Anthracene	1.29	1.24 (20/4)	0.29	18,621	55.9	325	0.01
Fluoranthene	0.265	1.25 (0/4)	0.29	41,687	125.1	726	0.003
Fluorene	1.69	1.20 (0/4)	2.19	5,012	15.0	88.2	0.03
Naphthalene	30	1.16 (20/4)	0.99	550	1.7	10.6	0.2
Phenanthrene	0.816	1.18 (25/4)	0.62	5,248	15.7	92.3	0.02
Pyrene	0.032	1.27 (23/4)	0.07	45,709	137.1	796	0.003
cPAHs							
Benzo(a)anthracene	0.01	1.27 (20/4)	0.18	1,380,384	4,141	24,020	0.0001
Chrysene	0.0015	1.27 (20/4)	0.11	245,470	736	4,272	0.0005
Benzo(b)fluoranthene	0.014	No Data	0.21	549,541	1,649	9,563	0.0002
Benzo(k)fluoranthene	0.00055	No Data	0.07	4,365,158	13,095	75,955	0.00003
Benzo(a)pyrene	0.003	1.35 (-/-)	0.22	398,107	1,194	6,928	0.0003
Dibenzo(a,h)anthracene	0.0005	1.28 (-/-)	0.13	1,659,587	4,979	28,878	0.0001
Benzo(g,h,i)perylene	0.00026	No Data	0.19	7,762,471	23,287	135,068	0.00002
Indeno(1,2,3-cd)pyrene	0.062	No Data	No Data	30,902,954	92,709	537,712	0.000004

Notes:

1. Source of solubility, S, specific density, and organic carbon partition coefficient, Koc, values: Montgomery and Welkom, 1990.
2. Specific density is the ratio of compound to water, (temperature of compound/temperature of water).
3. Biodegradation rate is low rate in groundwater. Source: Howard, et al., 1991.
4. Sorption coefficient, Kd= foc * Koc, where foc = 0.003.
5. Solute velocity is the product of the hydraulic conductivity (0.31 ft/day) and hydraulic gradient (0.005 ft/ft) divided by the effective porosity (0.25) and the retardation factor.

Table 4-3 Degradation Calculations

Compound	Groundwater Concentration ⁽¹⁾ (µg/L)	Biodegradation Rate, k ⁽²⁾ (per year)	Solute Velocity, v ⁽³⁾ (feet/year)	Degradation Time ⁽⁴⁾ (year)
Acenaphthene	49	1.1	1.7	3.5
Fluorene	21	2.19	0.03	1.4
Naphthalene	920	0.99	0.2	6.9
Phenanthrene	29	0.62	0.02	5.4

Notes:

1. Groundwater concentrations from Well 93-2S collected on March 10, 1996.
2. Biodegradation rate is low rate in groundwater. Source: Howard, et al, 1991.
3. Solute Velocity is the product of the hydraulic conductivity (0.31 ft/day) and hydraulic gradient (0.005 ft/ft) divided by the effective porosity (0.25) and the retardation factor.
4. Tie to biodegrade to a groundwater concentration of 1.0 µg/L.

Table 4-4 Summary and Comparison of Phase II Alternatives

Alternative	Effectiveness	Implementability	Cost
Continue Phase I Operations for the Indefinite Future	Provides effective hydraulic containment and some mass removal; effective treatment of extracted groundwater. Time to reach remediation levels approximately 1,700 years.	All systems exist, component replacements required over time. Need more capacity for managing treated water. ROD revision needed to extend time frame.	Capital Cost = \$0 O&M = \$275,000 per year Total PV = \$4.4 million
Expanded Phase I Operation	Limited by low permeability of aquifer. Extraction rate may not exceed Phase I, restoration time frame uncertain, possible 50 to 100 yrs.	Installation of an extensive well array is feasible; maintenance of those recovery wells is difficult because of aquifer characteristics.	Capital Cost = \$2.9 million O&M = \$500,000 per year Total PV = \$8.3 million
Modified Phase I for Product Recovery	Recoverable DNAPL removed in a short time frame (10-year estimate). Residual (immobile) DNAPL and the dissolved plume remain. Restoration time frame >1,700 years.	Enhancements to recovery not yet demonstrated. Conventional recovery easy to implement. ROD revision needed to exclude aquifer restoration as goal.	Capital Cost = \$130,000 O&M = \$190,000 per year Total PV = \$1.5 million (does not include cost for enhancements)
Modified Phase I for Containment	Dissolved plume effectively contained by downgradient pumping wells. Minimal mass removal, restoration time frame >1,700 years if at all.	New extraction well needed; all other systems exist. ROD revision needed to exclude aquifer restoration as goal and extend time frame.	Capital = \$110,000 O&M = \$190,000 per year Total PV = \$3.3 million
Monitored Natural Attenuation	Low permeability of surficial aquifer provides for effective containment; degradation occurs naturally. Restoration time frame >1,700 years.	Additional monitoring wells required. ROD revision needed to exclude aquifer restoration as goal and extend time frame.	Capital cost = \$0 O&M = \$100,000 per year Total PV = \$1.6 million
Institutional Controls	Risk controlled by absence of a complete pathway (DNRC controlled groundwater use area) and by aquifer characteristics. Restoration will occur through natural attenuation processes. Restoration time frame >1,700 years.	Controlled use designation from DNRC facilitated by support of local or state public health agency. ROD revision needed to exclude aquifer restoration as a goal.	Capital Cost = \$0 O&M = \$30,000 per year Total PV = \$0.5 million

4.3.7 Recommended Alternative

The Phase I groundwater remedy was implemented as required in the site ROD. Following 6 years of groundwater extraction and treatment, 2 percent of the total dissolved-phase contamination in the subsurface has been recovered due to limitations of the aquifer. At the current rate of recovery, the selected remedy will meet the ROD objectives in 1,700 years.

The review of alternatives presented above indicates that continued or expanded/modified Phase I operations will not meet the ROD goal of aquifer restoration within a reasonable time frame. Monitoring of the Phase I system and fate-and-transport analyses (Section 2) have shown that the low-permeability aquifer provides a natural containment barrier and, as a result, there is minimal demonstrable risk associated with the presence of contaminated groundwater at the Somers site. Therefore, BNSF proposes that a TI waiver be granted for the Somers site, and that institutional controls which meet the ROD's overall objectives of containing the plume, protecting Flathead Lake, and limiting exposure to human receptors under the conditions encountered at the site be implemented. This approach is discussed further in the next section

5 Technical Impracticability Evaluation

This Section presents the scope of the proposed TI waiver for the Somers site. Section 5.1 presents a review of applicable remediation levels and cleanup goals for groundwater. A discussion of the areal extent of the proposed TI waiver is presented in Section 5.2.

5.1 ARARs and Risk-Based Levels for Groundwater

The 1989 ROD for the Somers site established both groundwater ARARs and risk-based groundwater cleanup levels, and the ROD specified a remedy that was intended to restore groundwater. The groundwater ARARs in the ROD were based on Clean Water Act and Safe Drinking Water Act standards. The risk-based groundwater cleanup levels were based on the assumption that the remedy would achieve groundwater ARARs and on the following assumed exposure pathways: 1) shallow groundwater at the Somers site could be a future source of groundwater; 2) contaminants in the shallow groundwater at the Somers site could migrate to and impact a current or future source of drinking water; and 3) contaminants in the shallow groundwater at the Somers site could migrate to and impact the water quality of Flathead Lake.

In accordance with the National Contingency Plan (NCP), EPA completed issued a 5-year review of the remedy at the Somers site in February 1997 (EPA, 1997). That review recommended that some of the cleanup goals for the site be revised to reflect new scientific data and regulatory standards. In July 1998, EPA issued an ESD "to modify certain remediation criteria" in the ROD. The 1998 ESD did not waive ARARs but did provide revised ROD risk-based levels for groundwater, shown in Table 5-1. Due to the characteristics of site geology, hydrogeology and contaminant characteristics, restoration of the groundwater to the ARARs specified in the ROD is technically impracticable. Therefore, BNSF is requesting a TI waiver of groundwater ARARs in the ROD.

Based on specific conductance, the site groundwater is classified a Class II aquifer, suitable for use as a potable water supply. Data from the RD and the Phase I system indicate that, at best, a well-designed extraction well constructed with 50 feet of screen can produce no more than 1 gpm, on average, with the rate of production falling to 0.5 gpm (refer to Appendix B).

Table 5-1 Groundwater ARARs and Risk-Based Levels

Compound	1989 ROD Risk-Based Levels (µg/L)	1989 ROD ARARS (µg/L)	1998 ESD Modified Risk-Based Levels (µg/L)
Acenaphthene		20 ⁽²⁾	
Fluoranthene		42 ⁽²⁾	
Naphthalene		620 ⁽²⁾	
Benzene		5 ⁽³⁾	
Total PAH	0.030 ⁽¹⁾		40 ⁽¹⁾
Total CPAH		0.030 ⁽²⁾	0.047 ⁽¹⁾
Phenol		3,500/2,500 ⁽²⁾	6,000 ⁽¹⁾
Total Phenolics	15,000 ⁽¹⁾		6,000 ⁽¹⁾
Zinc		5,000 ⁽⁴⁾ /110 ⁽²⁾	

(1) Revised Risk Assessment Assumptions

(2) Clean Water Act Water Quality Criterion

(3) Safe Drinking Water Act Primary Maximum Contaminant Level (MCL)

(4) Safe Drinking Water Act Secondary MCL

Because of the extremely low extraction rate in the area of concern, the high iron concentration in the surficial aquifer, and the availability of potable water from the Somers municipal system, it is unlikely that the surficial aquifer downgradient of the Somers site could be developed as a source of potable water in the foreseeable future.

In Section 2.5.3 of this TI evaluation, the possibility that contaminated groundwater from the Somers site could migrate to and impact either the municipal water supply or Flathead Lake was examined. In both cases, the likelihood of any adverse impact was shown to be minimal based on a conservative groundwater modeling scenario. Based on these analyses, minimum periods of 500 to 5,000 years would be required for the most mobile constituent (naphthalene) to migrate to either the municipal water supply or Flathead Lake, respectively.

The evaluation of the Phase I system performance presented in Section 3 indicates that full aquifer restoration (as defined in the 1989 ROD), cannot be achieved within a reasonable time frame. Following 6 years of system operation, 2 percent of the DNAPL contamination estimated to remain in the subsurface has been removed. Additionally, groundwater quality immediately adjacent to the treatment area has not been improved. These data indicate that the restoration of the surficial aquifer at the Somers site to meet ARARs will

not likely be achieved within any reasonable restoration time frame. The primary impediment to restoration of the aquifer is the inability to extract contaminants or circulate nutrient-enriched water effectively. The ability of other potential groundwater remedial alternatives to meet this restoration time frame was discussed in Section 4 of this TI evaluation. None of those alternatives, including those which investigated options for expanded or modified Phase I operations, were judged to be able to restore the surficial aquifer to meet ARARs within a reasonable time frame.

5.2 Areal Extent of the Technical Impracticability Waiver

BNSF is requesting to apply the TI waiver to those areas of the surficial aquifer which contain residual creosote contaminated soil that are a continuing source to groundwater as well as areas where the groundwater is still impacted and does not currently comply with ARARs. The boundary of the TI waiver area is shown on Figure 5-1. The TI boundary encompasses all wells that have exceeded ARARs in the past 3 years.

Conservative assumptions were made in estimating the TI boundary to include downgradient areas containing groundwater to account for seasonal changes in groundwater direction and concentration¹⁷. The vertical extent of the TI waiver is the full thickness of the surficial aquifer only. The ARARs to be waived within the TI boundary are shown in Table 5-1. Protectiveness of human health will be achieved through the designation of a Controlled Groundwater Use Area to prevent the installation of groundwater supply wells, thereby eliminating the groundwater exposure pathway.

¹⁷ As discussed in Section 3, seasonal trends have not been observed to be statistically significant.

6 Recommended Action

Based on the inability of the current groundwater remedy to restore groundwater to remediation levels and the hydrogeologic and contaminant barriers that preclude the installation of an effective groundwater remedy, it is reasonable to conclude that restoration of the surficial aquifer at the Somers site to remediation levels cannot practicably be accomplished within a reasonable time frame. The barriers to aquifer restoration are:

Aquifer Permeability. EPA defines "aquifers of very low permeability" such as that present at the Somers site as being a "hydrogeologic limitation to aquifer remediation" by complicating the "extraction or in situ treatment of contaminated groundwater" (EPA, 1993). The low permeability of the aquifer limits dissolved-phase DNAPL recovery using currently available remedial methods. The primary impediment to restoration of the aquifer is the inability to extract contaminants or circulate nutrient-enriched water effectively. The ability of other potential groundwater remedial alternatives to meet the groundwater restoration goals was discussed in Section 4 of this TI evaluation. None of the alternatives, including those which investigated options for expanded or modified Phase I operations, were judged to be able to meet the ROD goal of restoring the surficial aquifer.

Contaminant Characteristics. DNAPLs are often particularly difficult to locate and remove from the subsurface due to their ability to sink through the water table and penetrate deeper portions of aquifers (EPA, 1993). In the subsurface at the Somers site, DNAPL is observed in root traces and in some localized, discontinuous sand lenses above a depth of 30 to 45 feet bgs (refer to the groundwater conceptual model; Figure 2-6). DNAPL is present sporadically throughout the soil matrix and a discrete, recoverable pool of DNAPL has not been encountered. The contaminants present at the site are largely hydrophobic, meaning that they are fairly insoluble in water and tend to sorb to soil particles. As a result, residual DNAPL is generally not capable of migrating or being displaced by normal groundwater flow, which magnifies the difficulty of recovery. The discontinuous distribution of DNAPL in the subsurface coupled with the inability to circulate large amounts of water from the aquifer greatly complicates DNAPL removal.

The factors listed above also reduce the potential for impacts to human health or the environment to occur. Specifically, the low permeability of the surficial aquifer downgradient of the Somers site, coupled with the presence of high iron concentrations in the aquifer and the ready availability of potable water from the Somers municipal system makes it very unlikely that this aquifer could be used as a potable water supply. Similarly, the potential for contaminated groundwater from the Somers site to migrate to either the municipal water supply or Flathead Lake is unlikely given, again, the low permeability of the aquifer and the low mobility of the contaminants present.

Based on the lines of evidence discussed, it is technically impracticable to effectively remove the contaminants present in the surficial aquifer at the Somers site. As long as DNAPL remains in the subsurface, it will provide an ongoing source of the dissolved-phase contaminant plume and ARAR-based cleanup levels will continue to be exceeded.

6.1 Recommended Action

Under a TI waiver, alternative, protective remedial strategies for a site will be established when restoration of groundwater to meet ARARs is judged to be technically impracticable. Recommendations for modifying the remedy are provided to ensure that the ROD's overall goal of protecting human health and the environment is met. These recommendations are:

- BNSF is requesting a waiver be implemented by EPA through an ESD waiving the ARARs set forth in the ROD. This waiver would be applied to an area defined as the portion of the surficial aquifer as shown in Figure 5-1.
- A Controlled Groundwater Use Area designation is being sought to prohibit the installation of groundwater supply wells. The Controlled Groundwater Use Area is shown in Figure 6-1.
- A groundwater monitoring program of appropriate frequency and extent would be implemented to monitor plume stability and determine the need for additional remedial action if the groundwater plume expanded to outside the waiver area.

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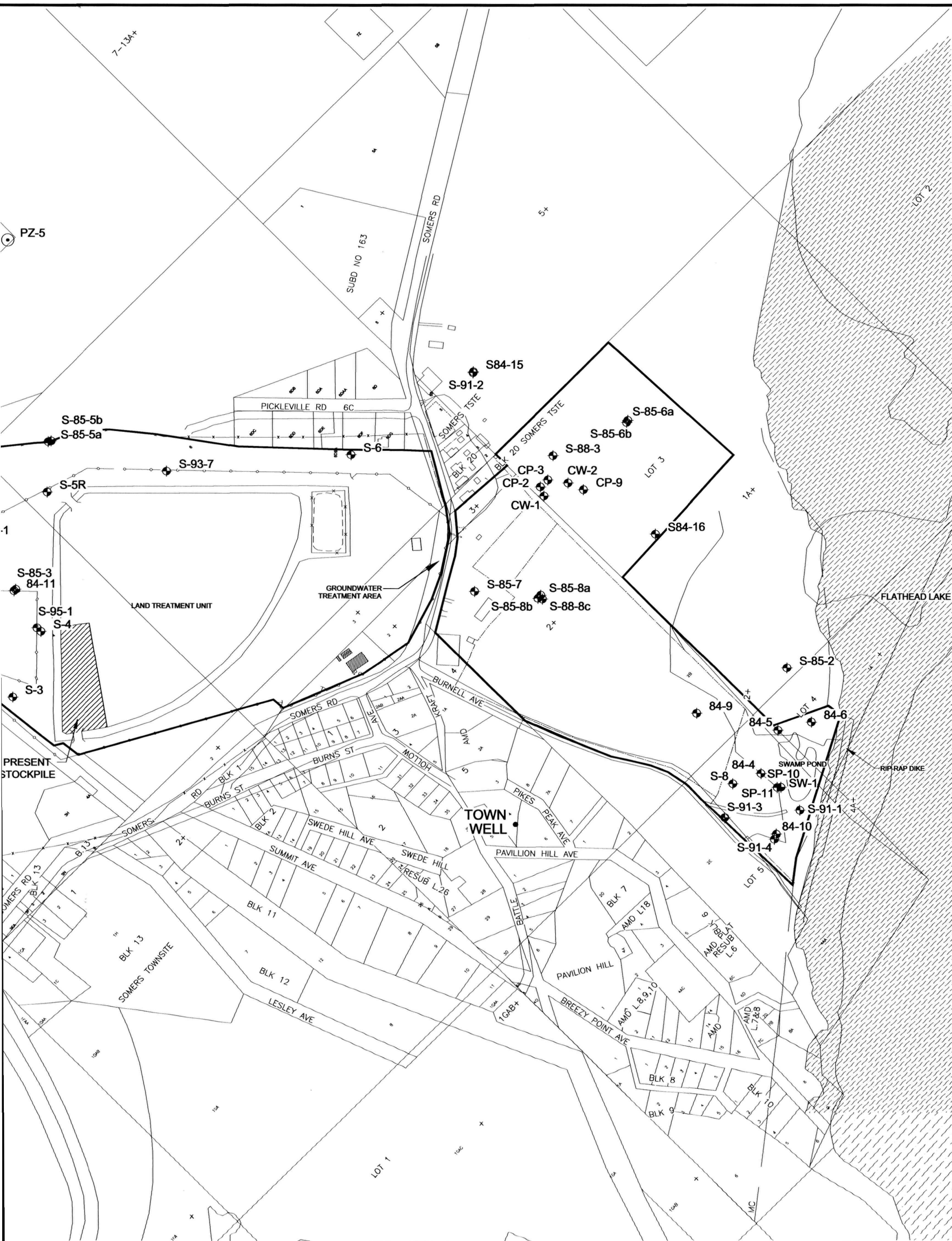
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Technical Impracticability Evaluation
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BNSF, Sommers, Montana (BN080-01860-240)

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SITE PROPERTY BOUNDARY MAP

FIGURE 1-1





Technical Impracticability Evaluation
for Groundwater Restoration
BNSF, Sommers, Montana (BN080-01860-240)

DATE: 11/26/02	DRWN: E.S.S./DEN
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HISTORICAL SITE FEATURES AND STRUCTURES

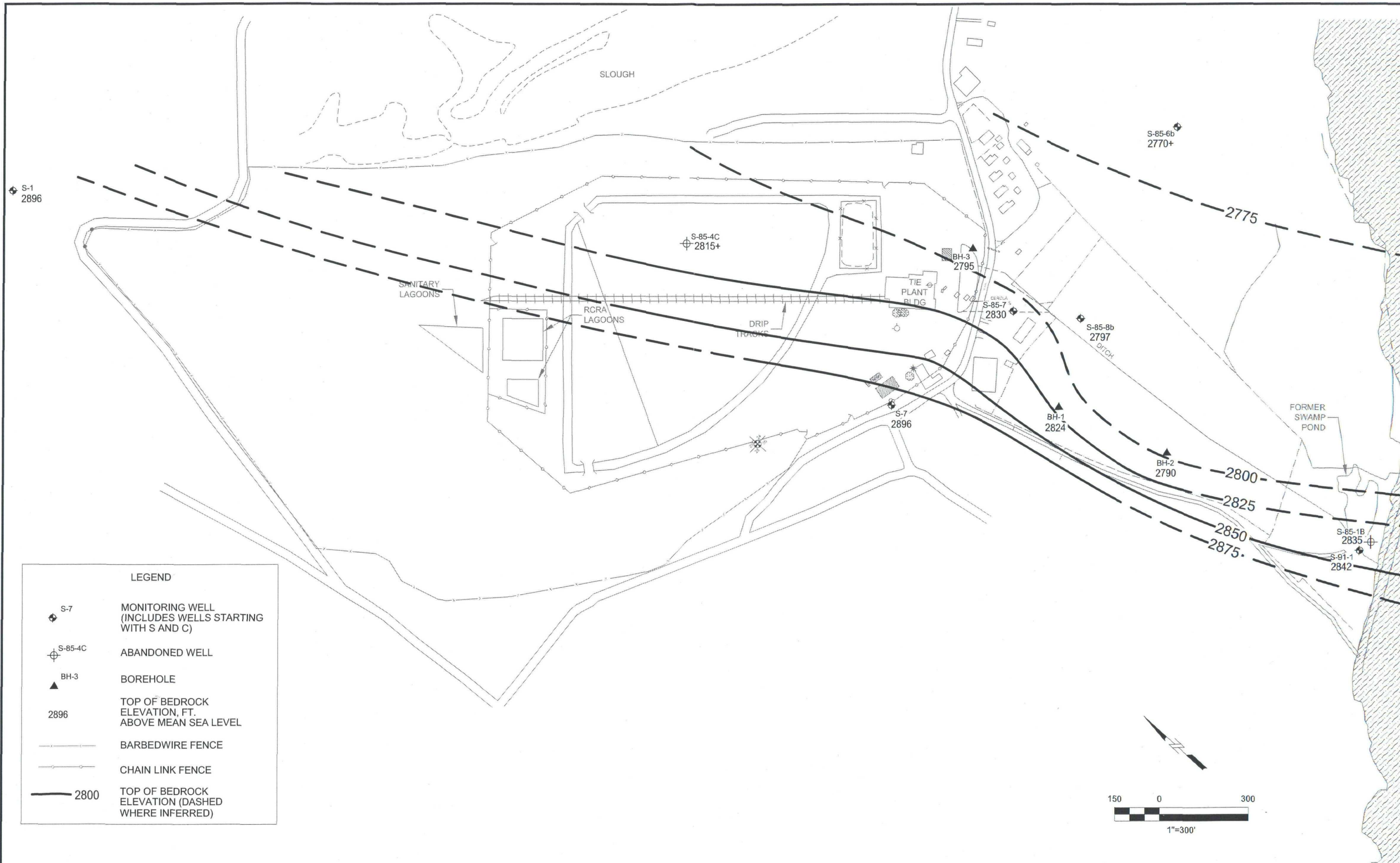
FIGURE 1-2



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FIGURE 2-1

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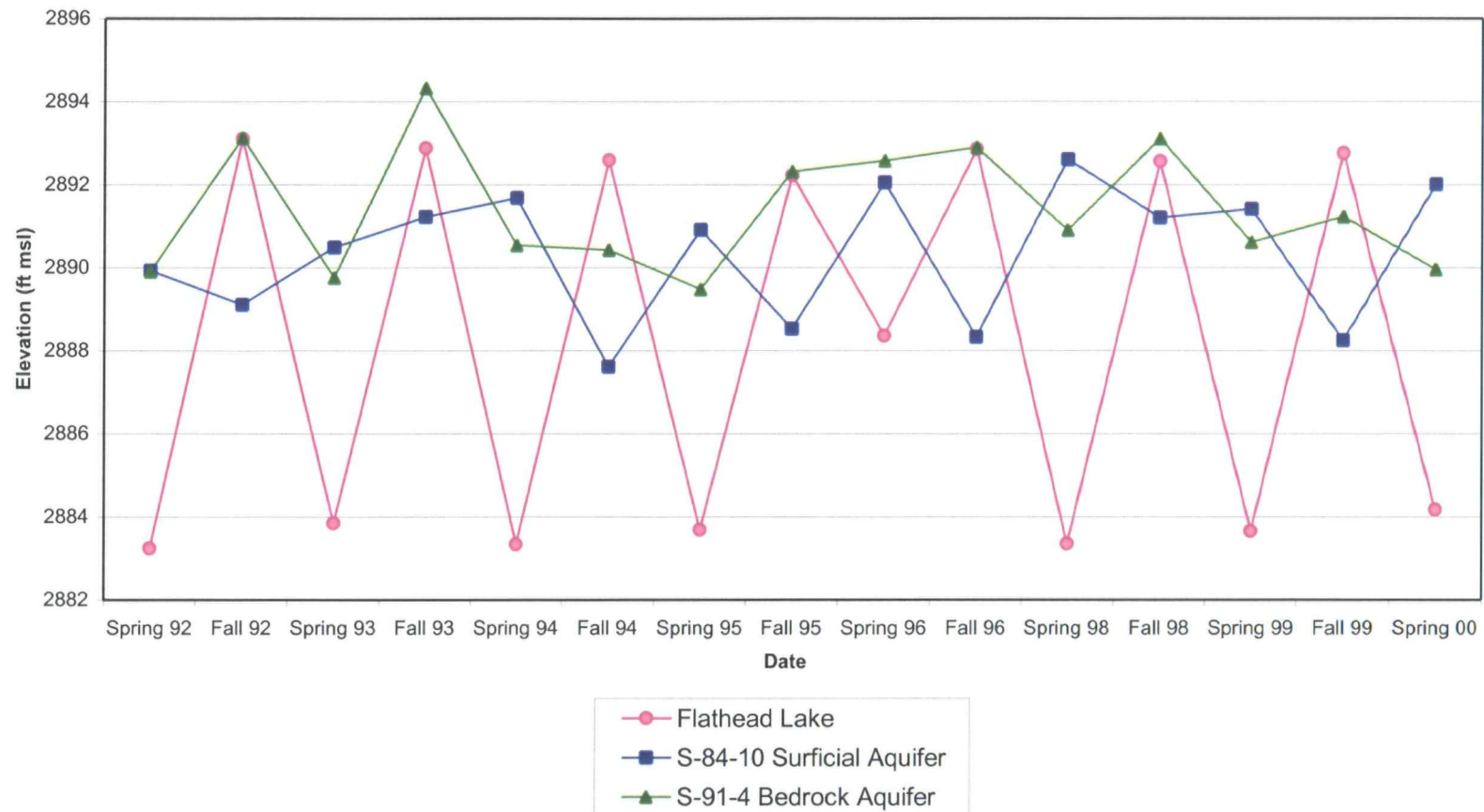
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**TOP OF BEDROCK
CONTOUR MAP**

FIGURE 2-2

Figure 2-3
Flathead Lake Elevation, Surficial and Bedrock Aquifer Hydrograph
 Technical Impracticability Evaluation for Groundwater Restoration - Somers, MT



Note = Elevations not measured in Spring and Fall 1997, due to ice and overflowing wells.

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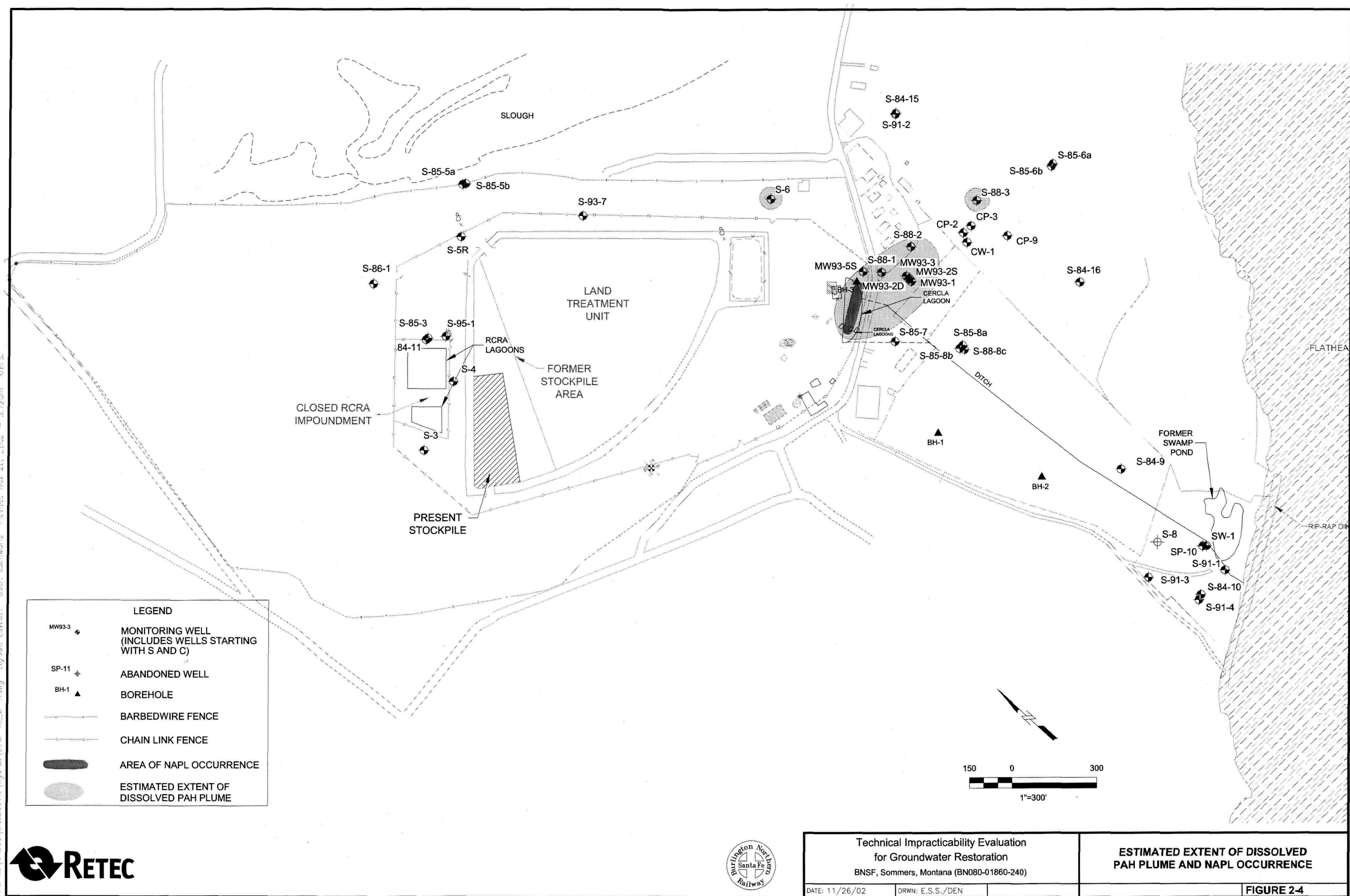
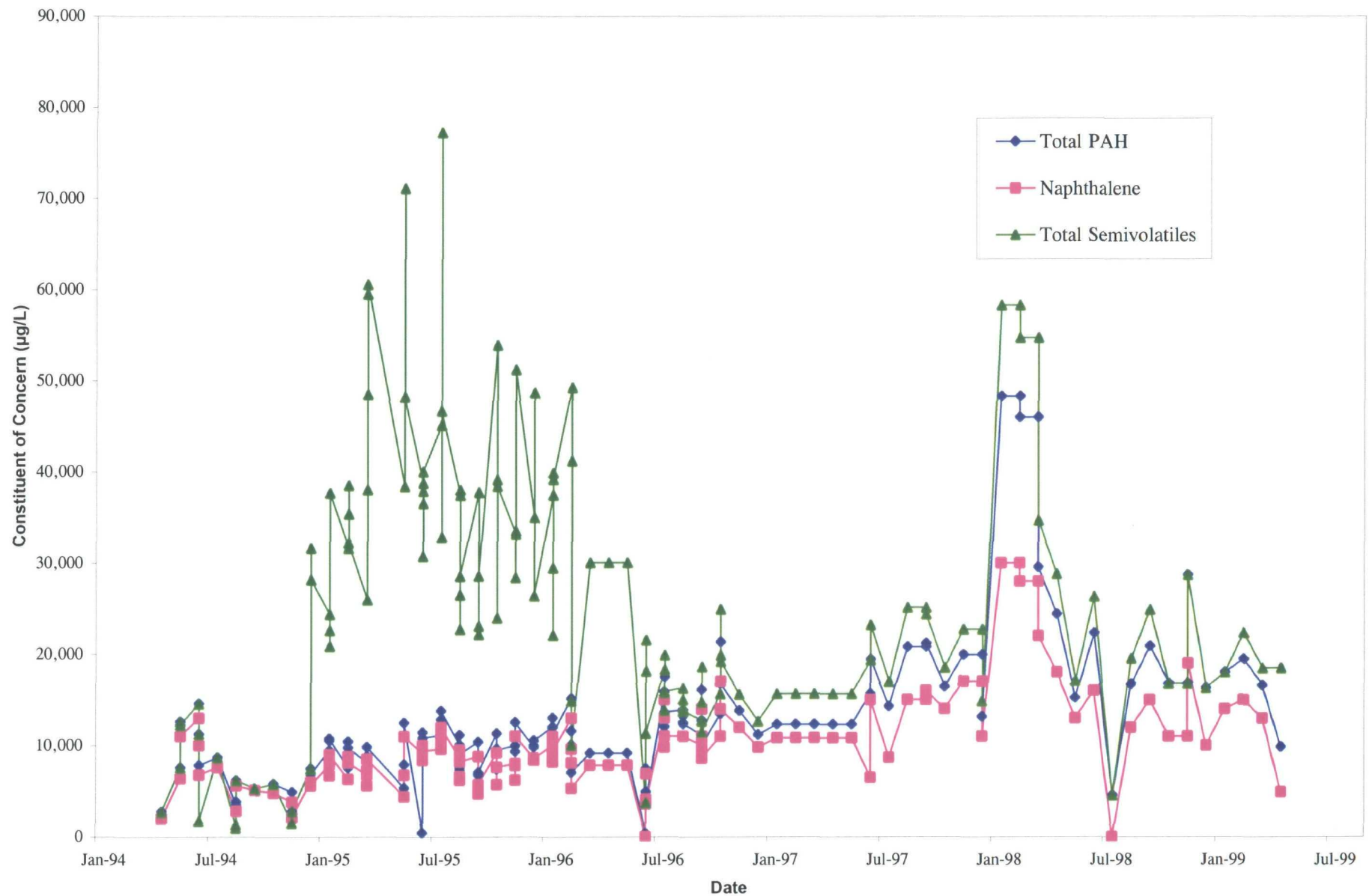
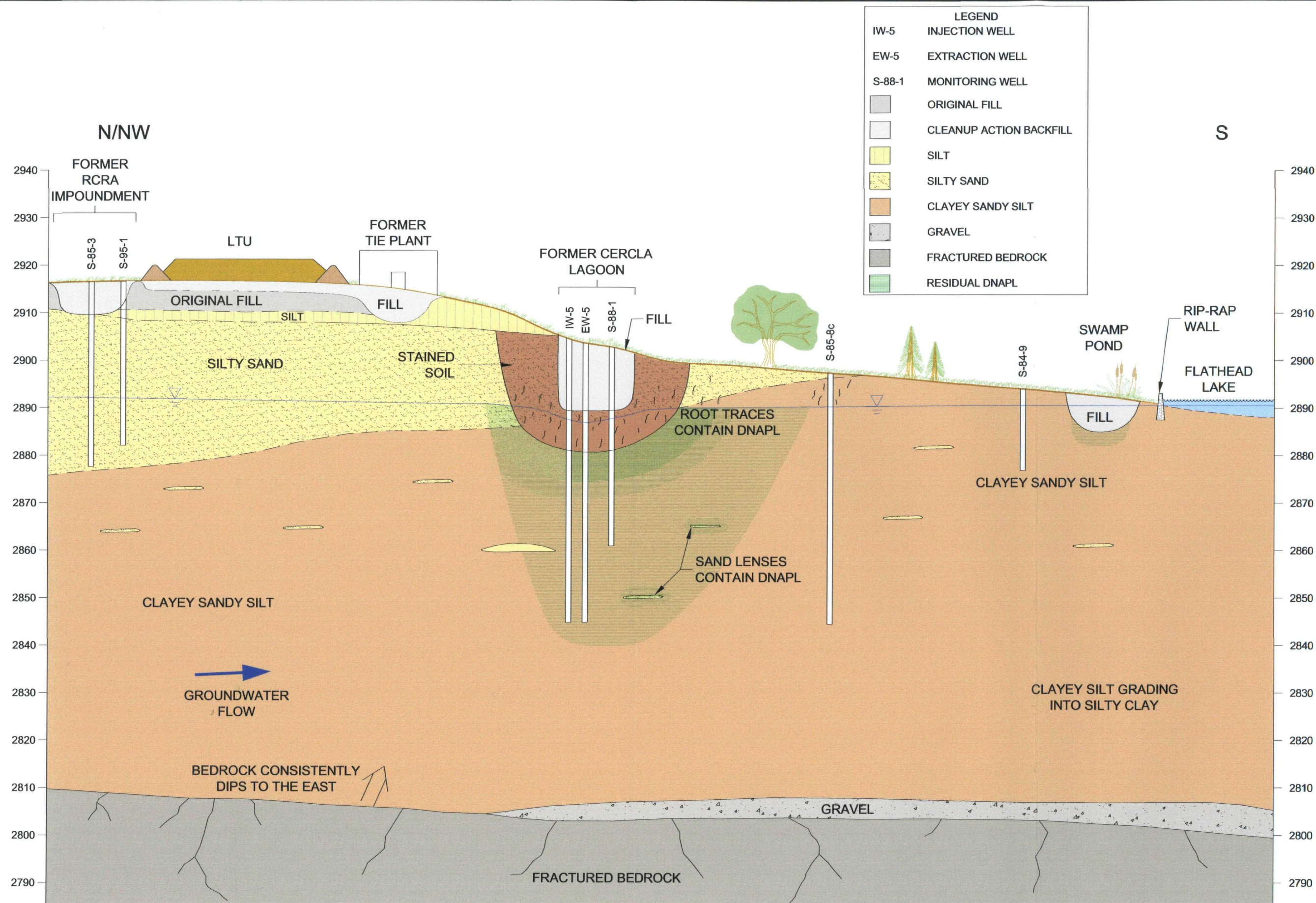


Figure 2-5
Summary of Influent Water Quality - Phase I Treatment System
Technical Impracticability Evaluation for Groundwater Restoration - Somers, MT



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GROUNDWATER CONCEPTUAL MODEL
BNSF SOMMERS, MONTANA

FIGURE 2-6

Figure 3-1
Summary of Individual and Combined Extraction Well Performance
Technical Impracticability Evaluation for Groundwater Restoration - Somers, MT

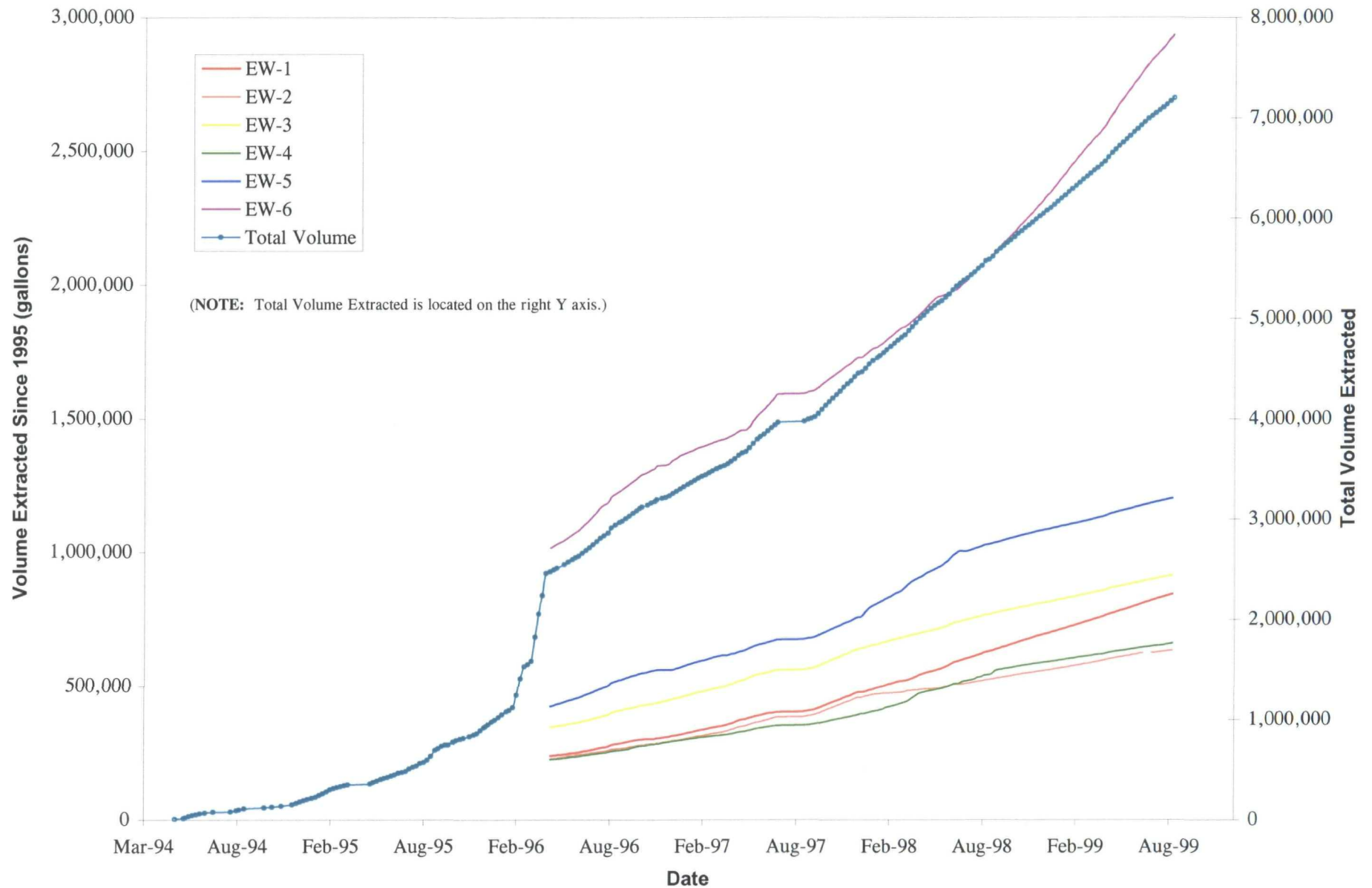


Figure 3-2
Fluctuation in Extraction Rate with Time
Technical Impracticability Evaluation for Groundwater Restoration - Somers, MT

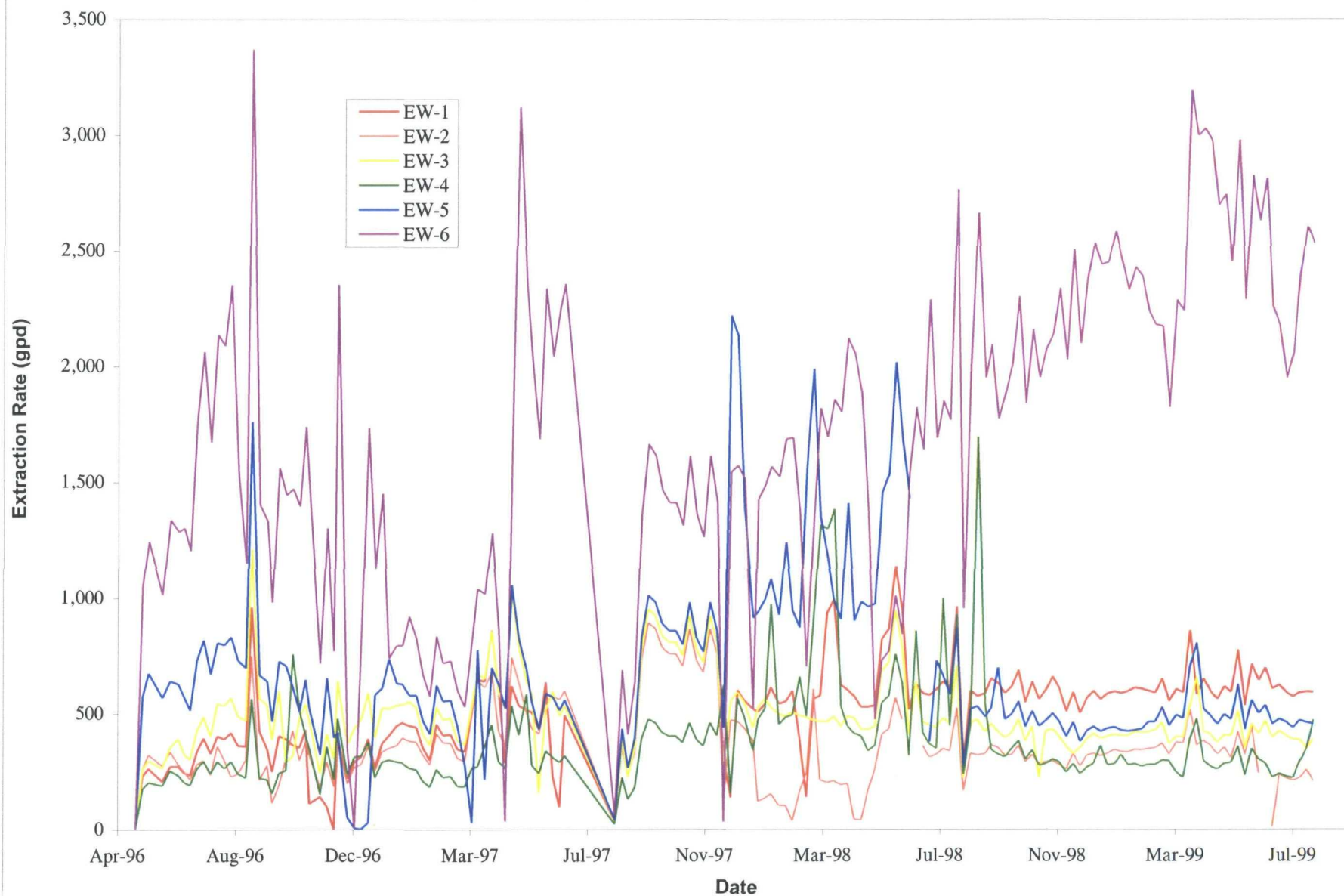
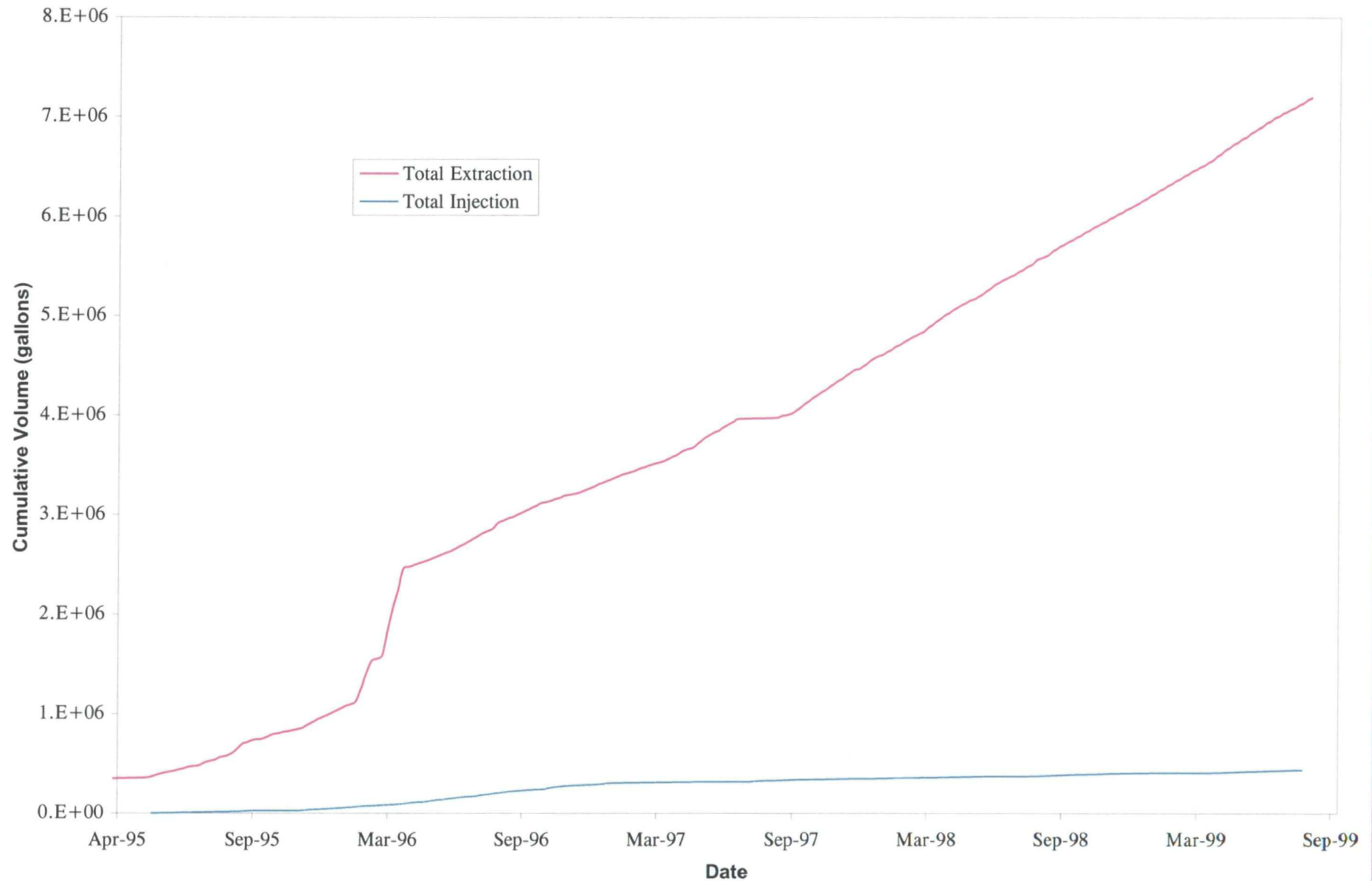
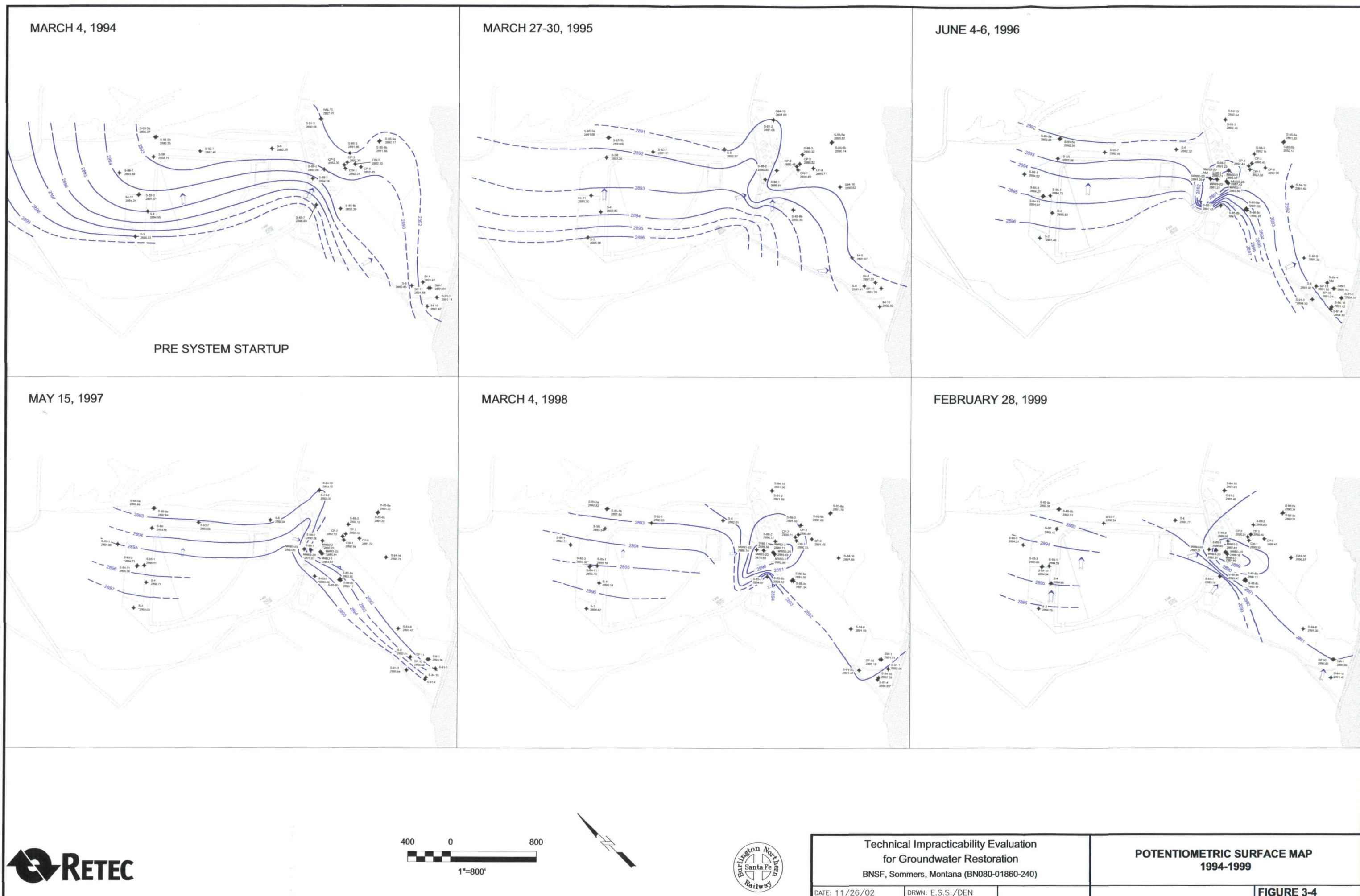


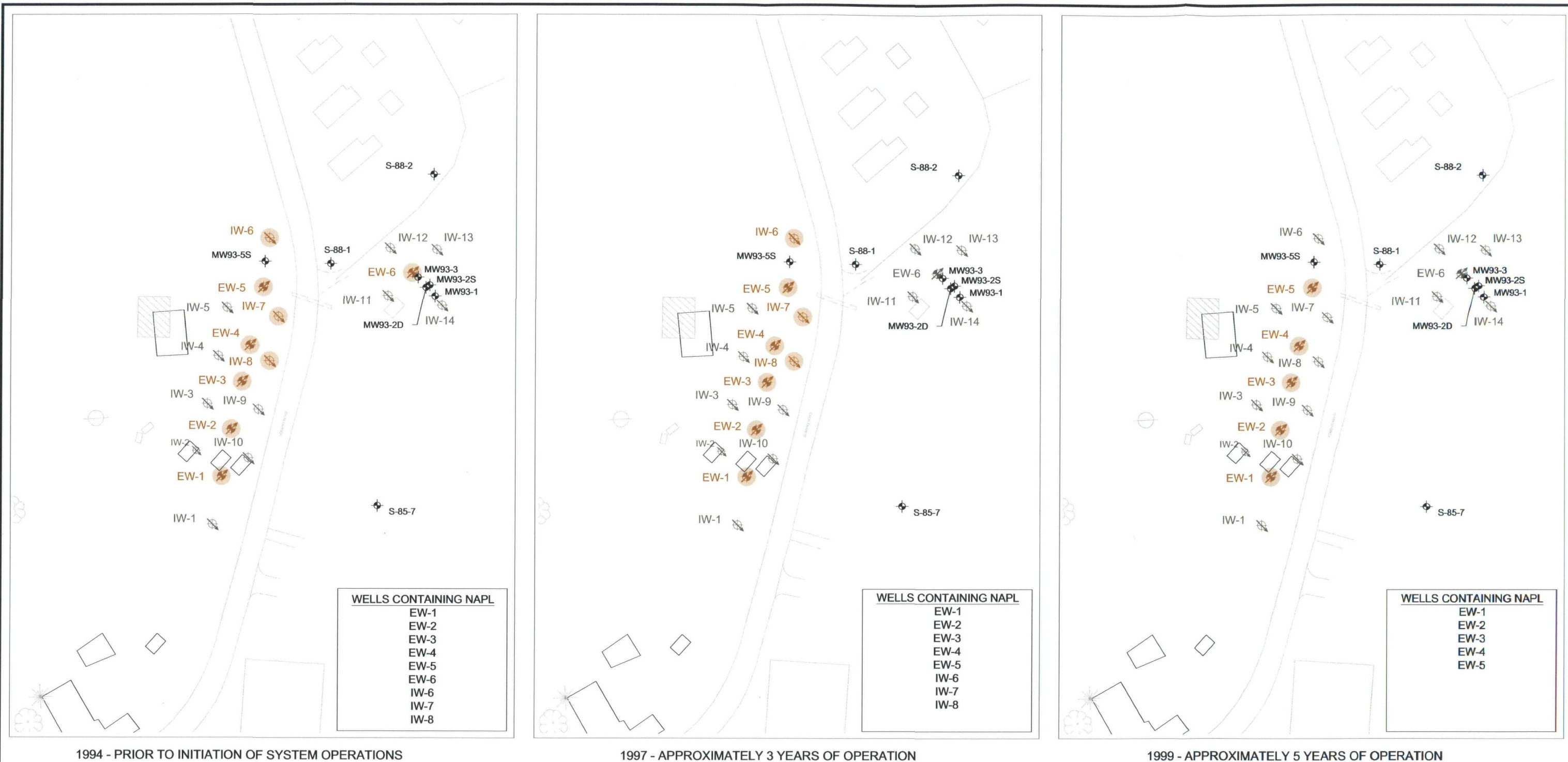
Figure 3-3
Comparison of Injection and Extraction System Performance
Technical Impracticability Evaluation for Groundwater Restoration - Somers, MT



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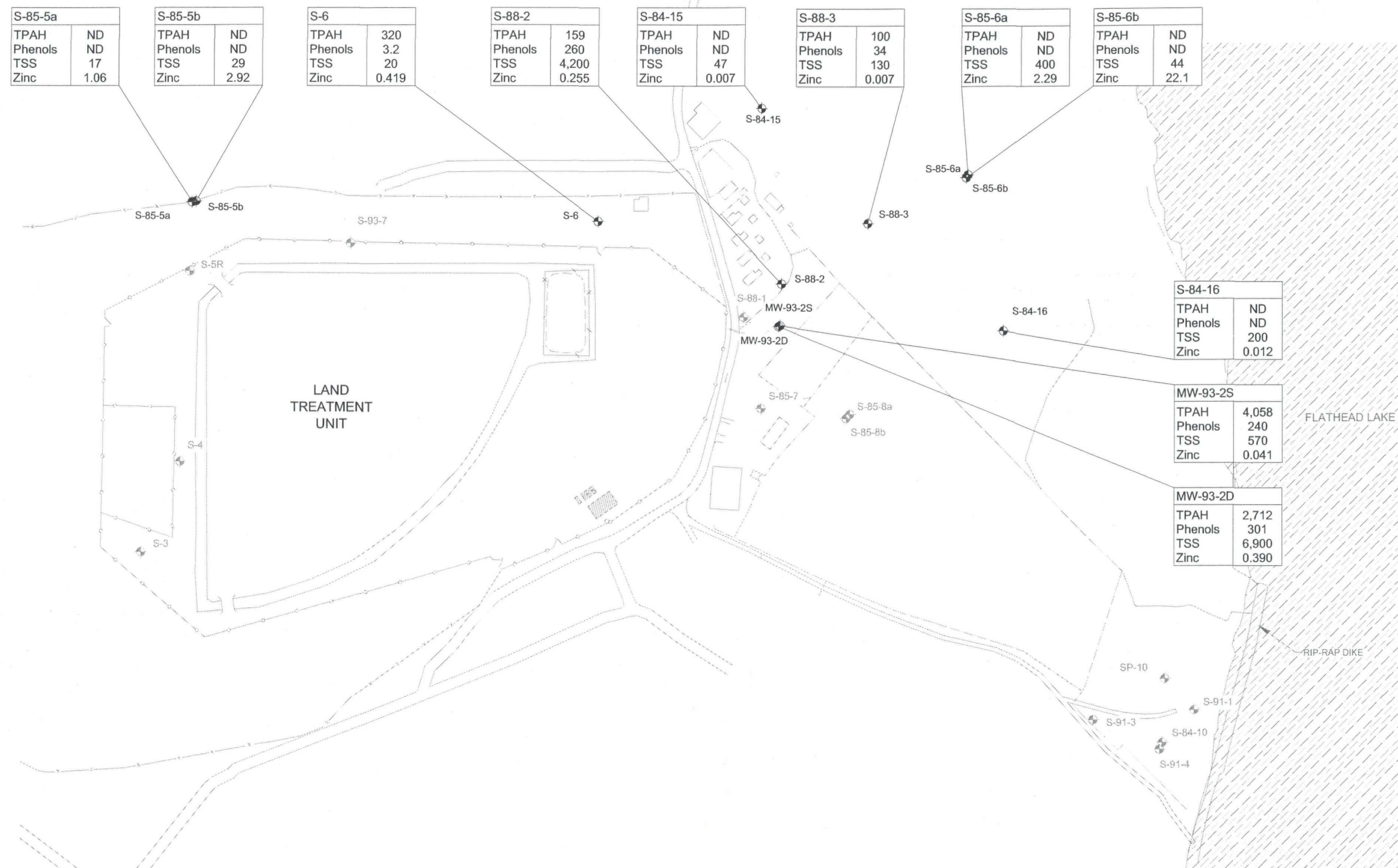
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**EXTRACTION & INJECTION WELLS
CONTAINING DNAPL**

FIGURE 3-5

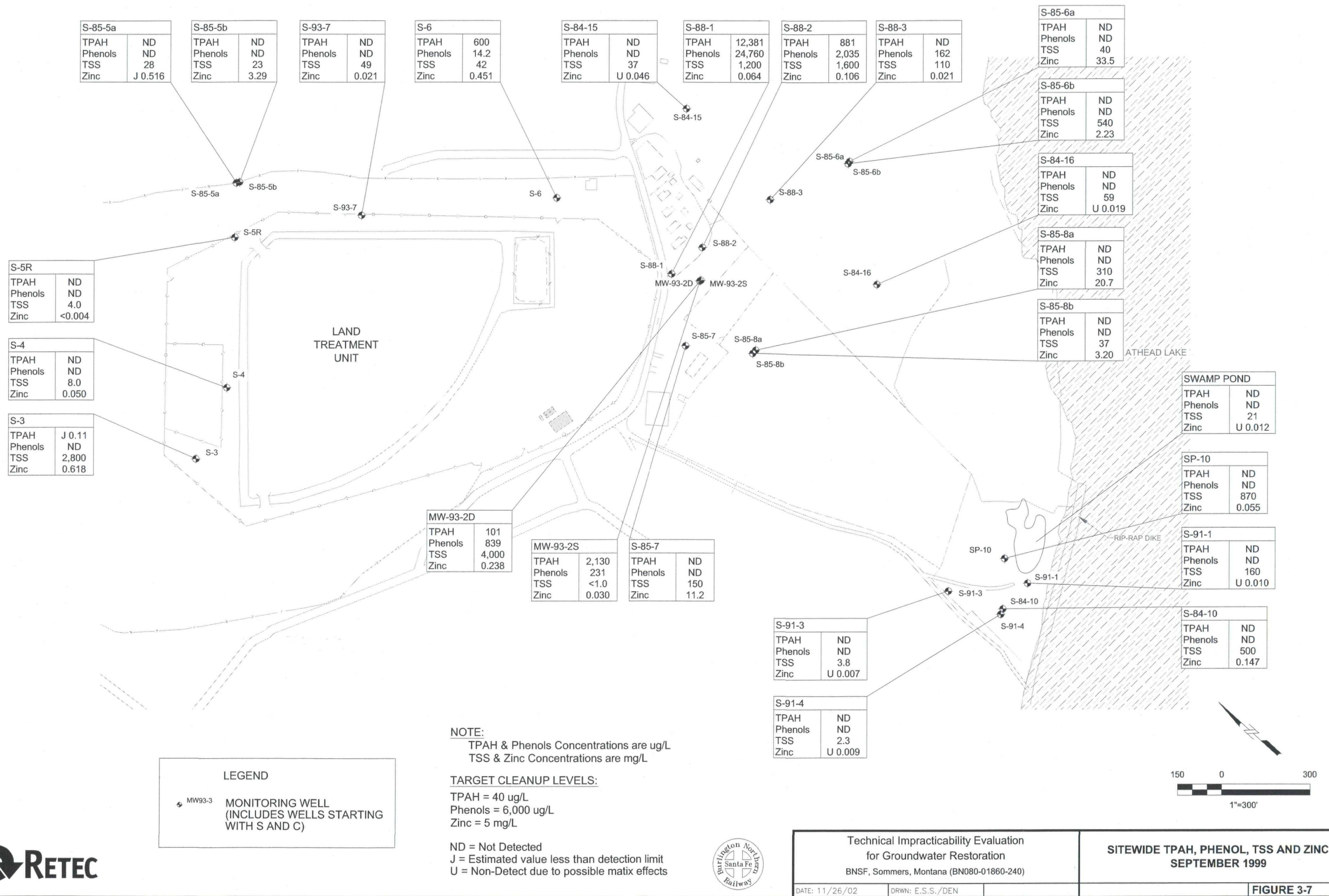
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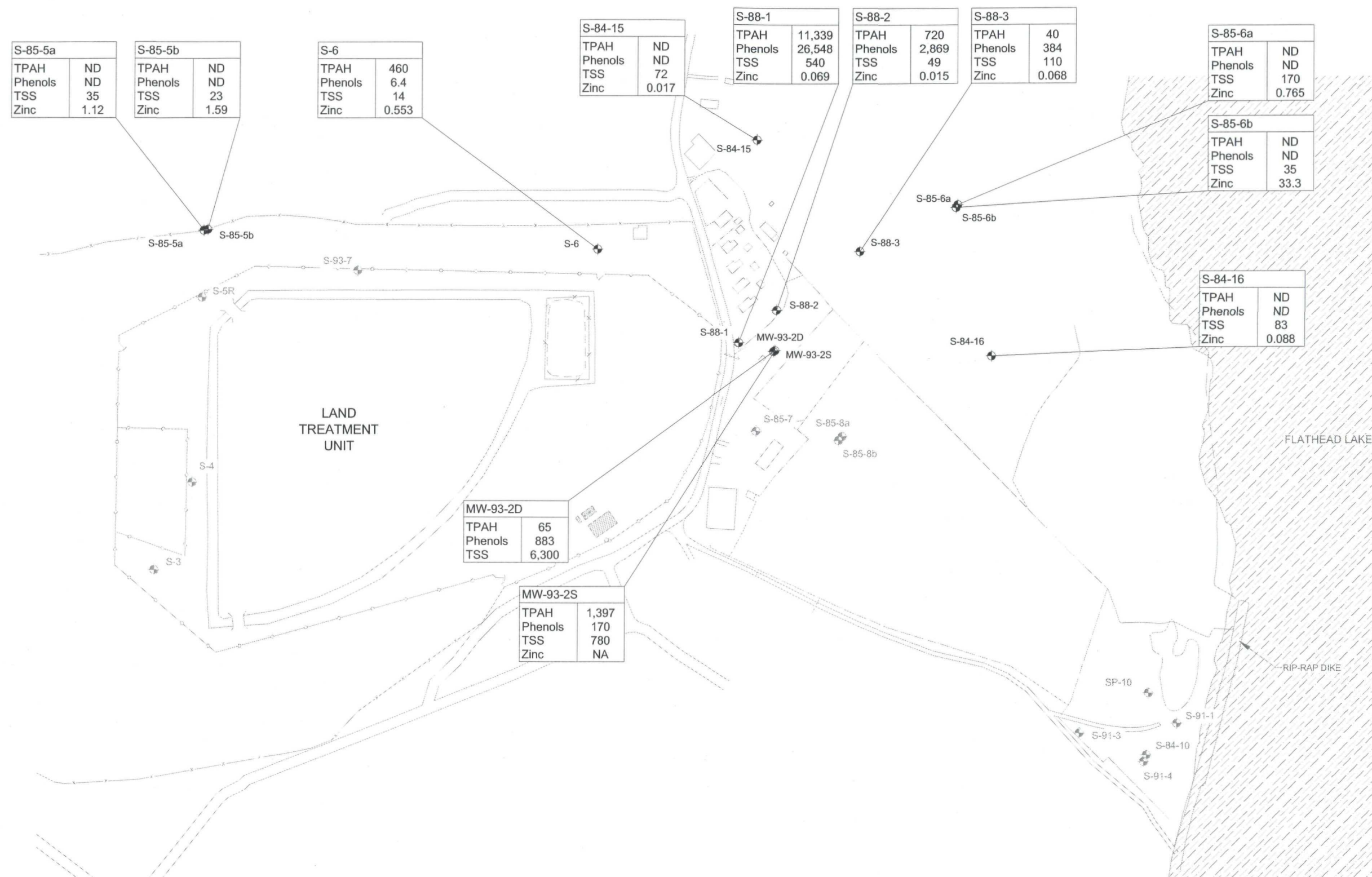
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FIGURE 3-6

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LEGEND

● MW93-3 MONITORING WELL
(INCLUDES WELLS STARTING
WITH S AND C)

NOTE:

TPAH & Phenols Concentrations are ug/L
TSS & Zinc Concentrations are mg/L

TARGET CLEANUP LEVELS:

TPAH = 40 ug/L
Phenols = 6,000 ug/L
Zinc = 5 mg/L

ND = Not Detected



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SITEWIDE TPAH, PHENOL, TSS AND ZINC
DECEMBER 1999

FIGURE 3-8



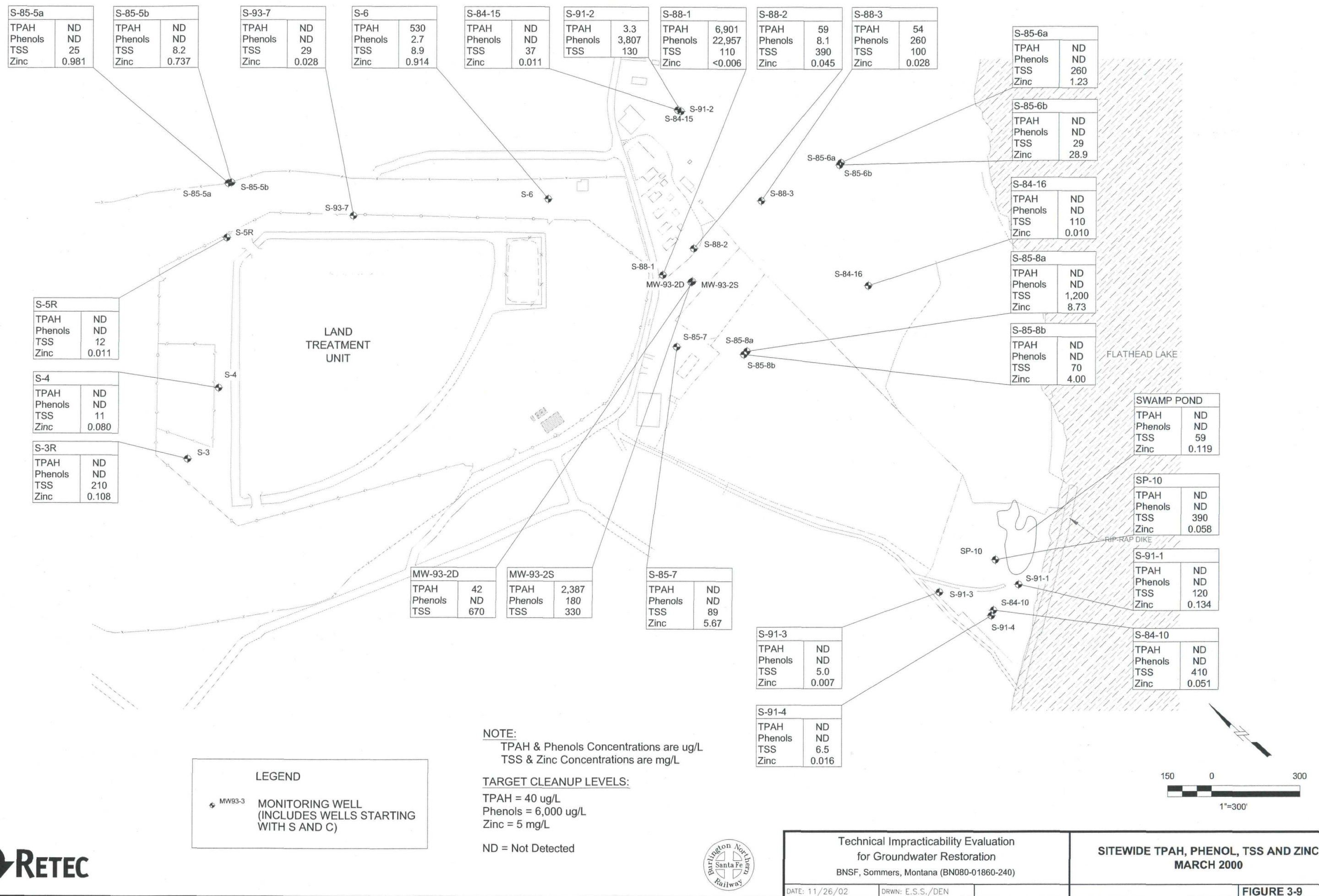
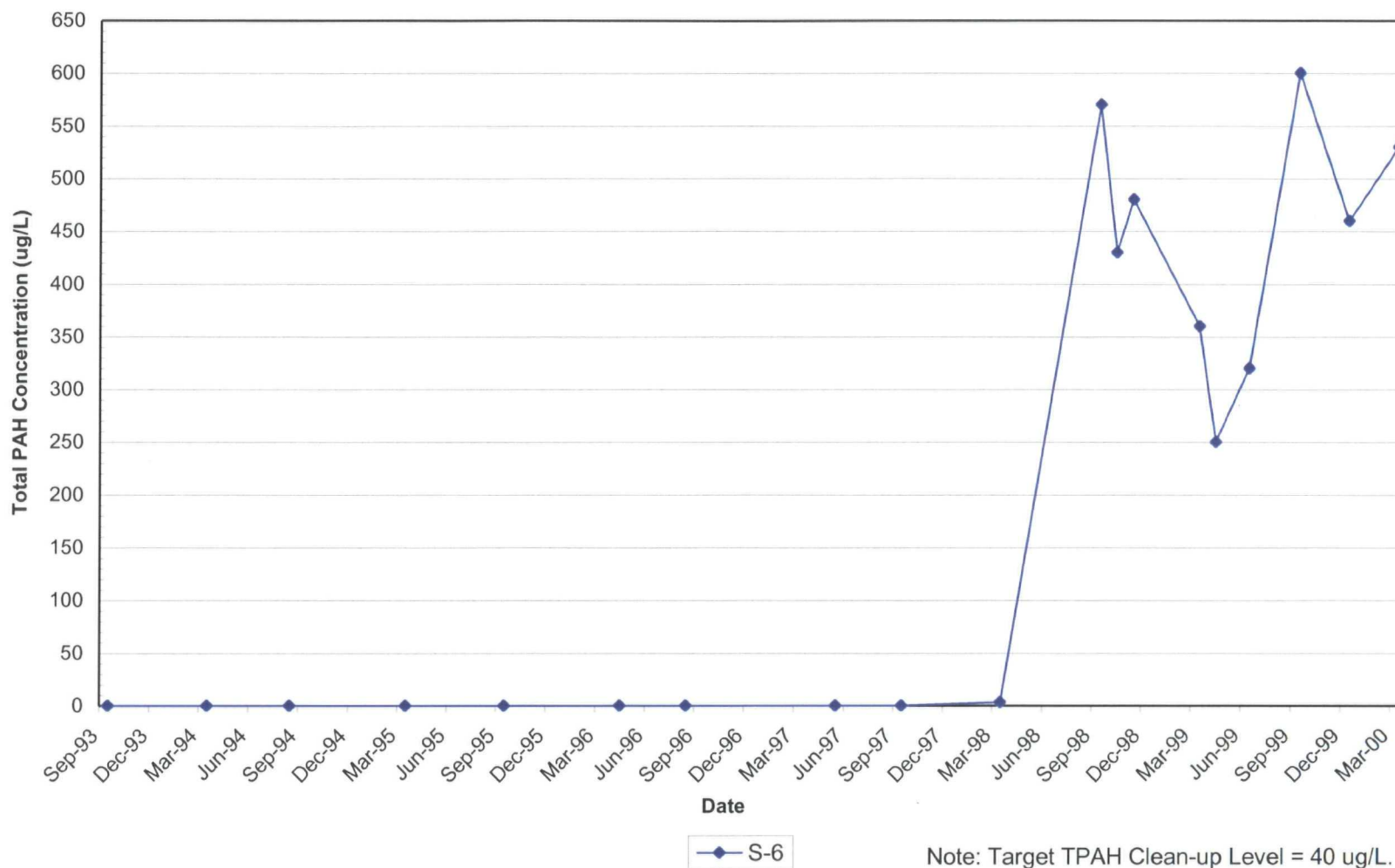
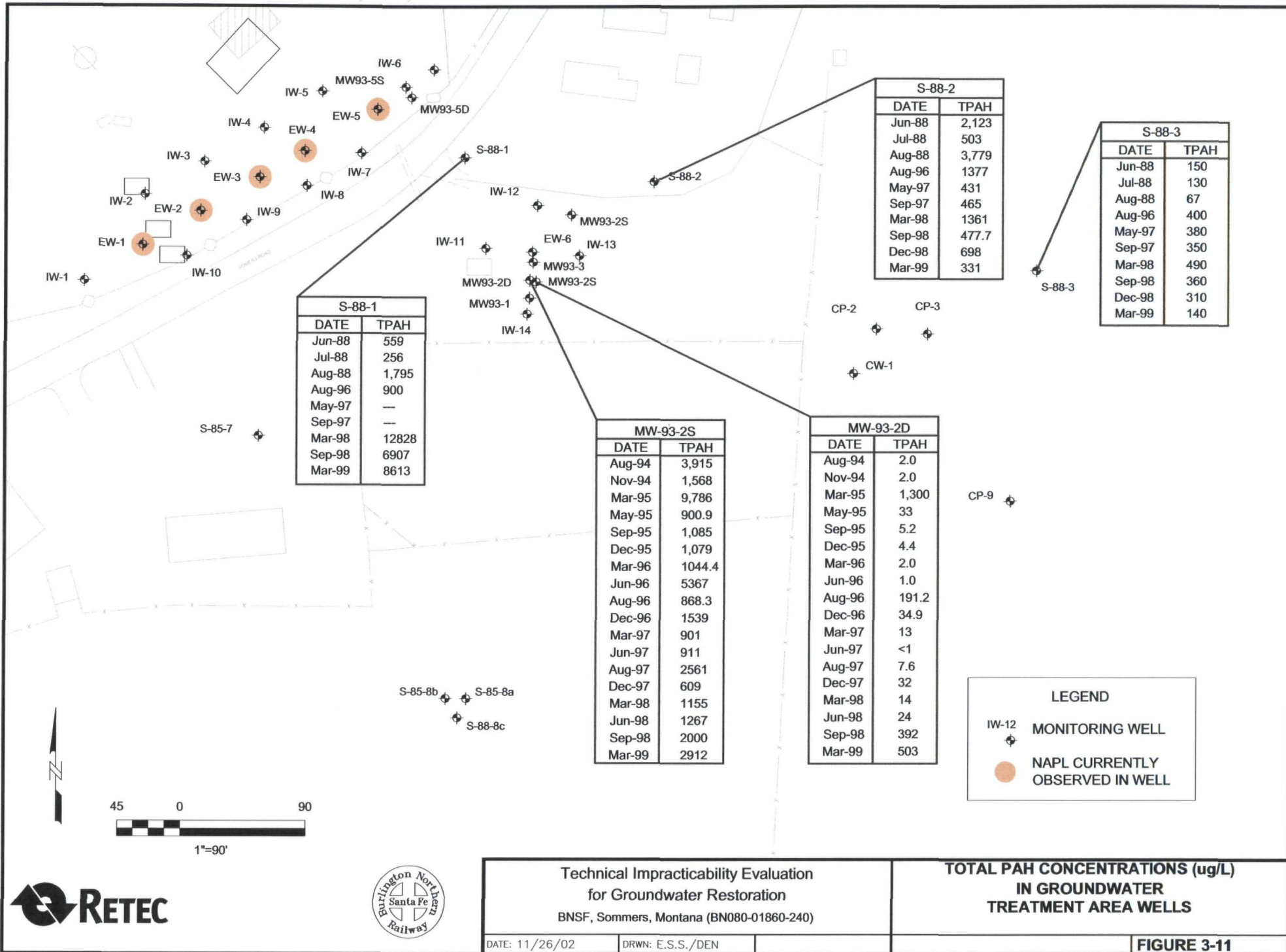


Figure 3-10
Total PAH Concentration in Well S-6 (ug/L)
Technical Impracticability Evaluation for Groundwater Restoration - Somers, MT





Technical Impracticability Evaluation
for Groundwater Restoration
BNSF, Sommers, Montana (BN080-01860-240)

DATE: 11/26/02

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**TOTAL PAH CONCENTRATIONS (ug/L)
IN GROUNDWATER
TREATMENT AREA WELLS**

FIGURE 3-11

Figure 3-12
Total PAH Concentrations for Wells MW-93-2S and MW-93-2D
Technical Impracticability Evaluation for Groundwater Restoration - Somers, MT

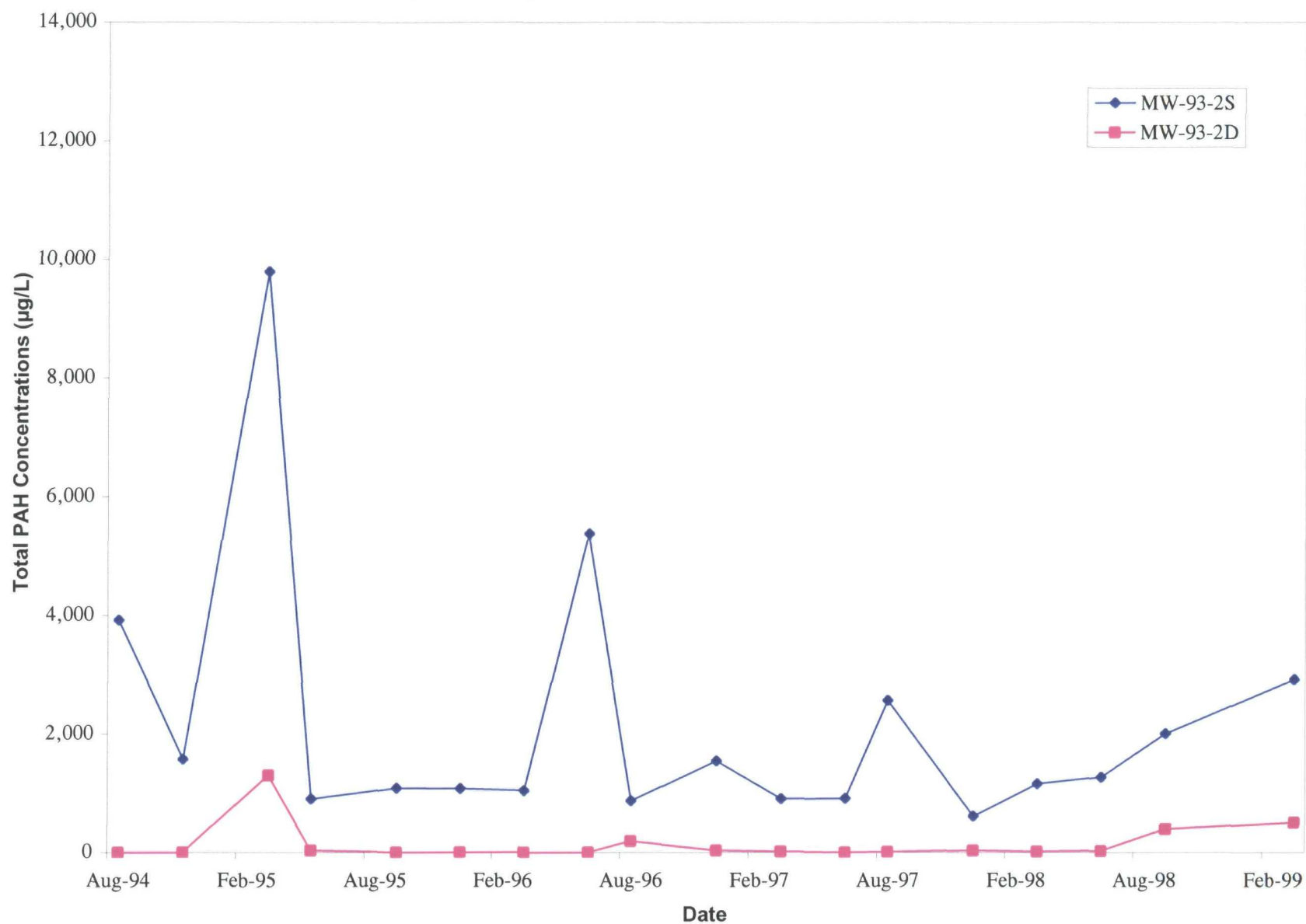
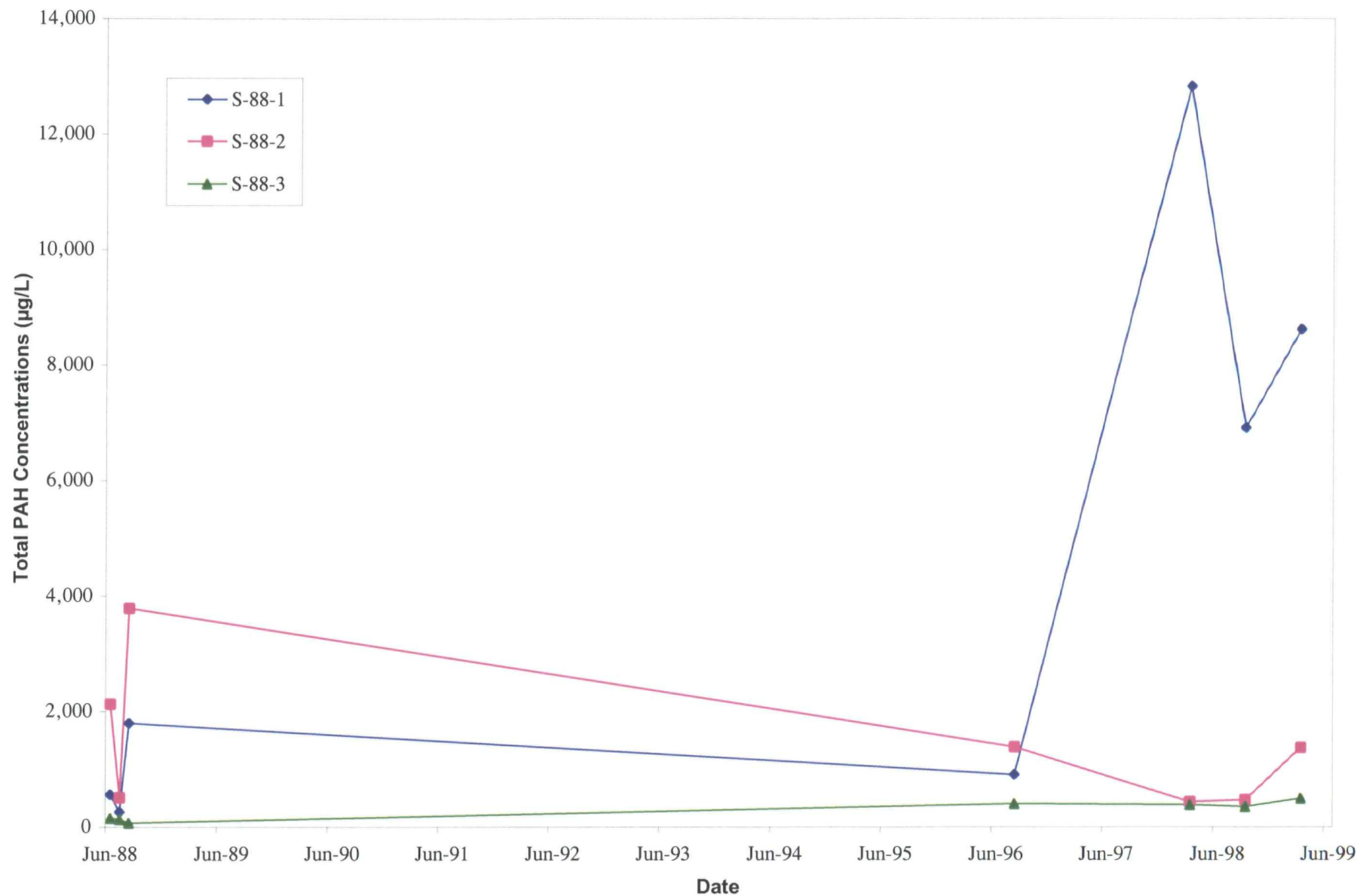
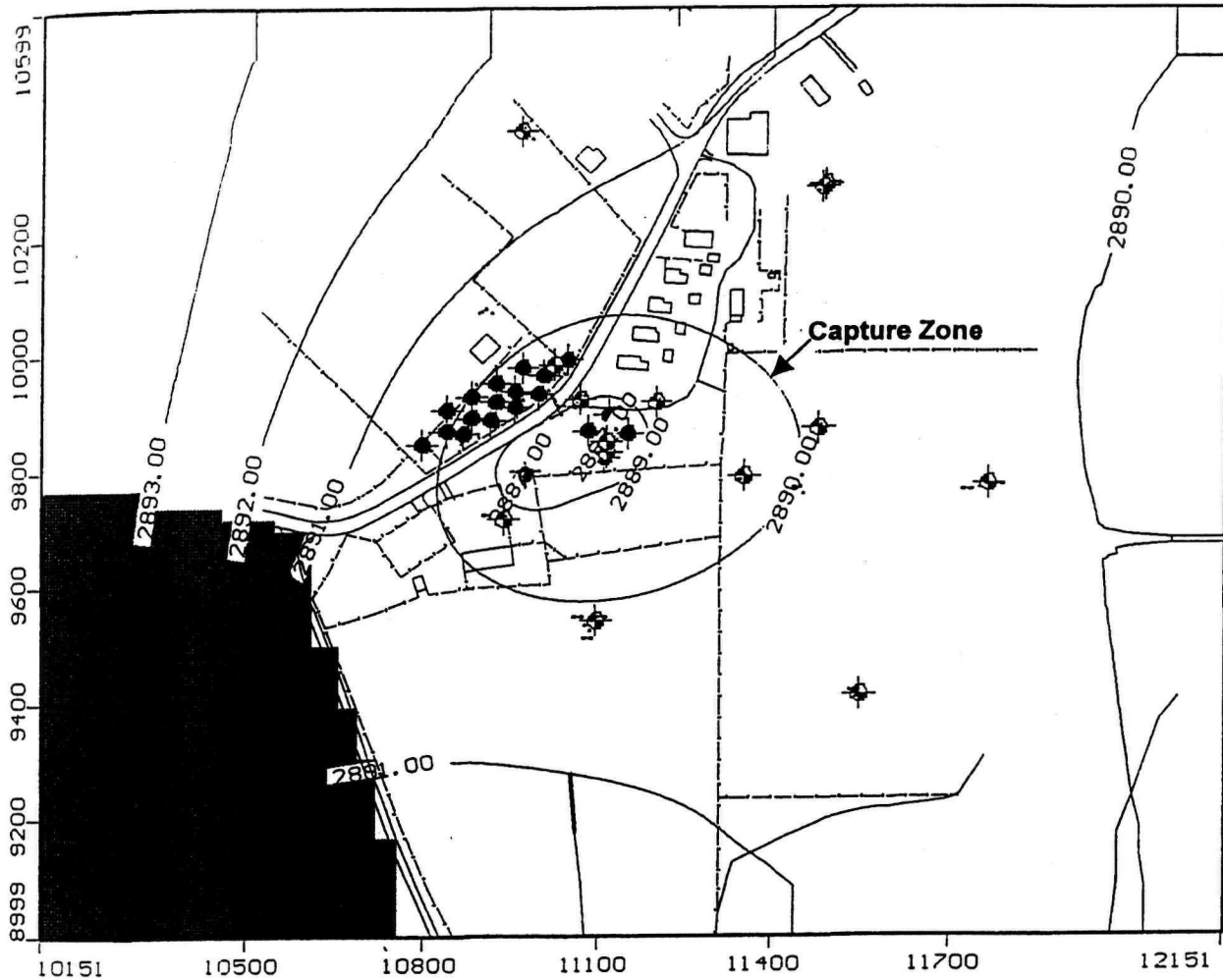


Figure 3-13
Total PAH Concentrations in Wells S-88-1, S88-2 and S-88-3
Technical Impracticability Evaluation for Groundwater Restoration - Somers, MT



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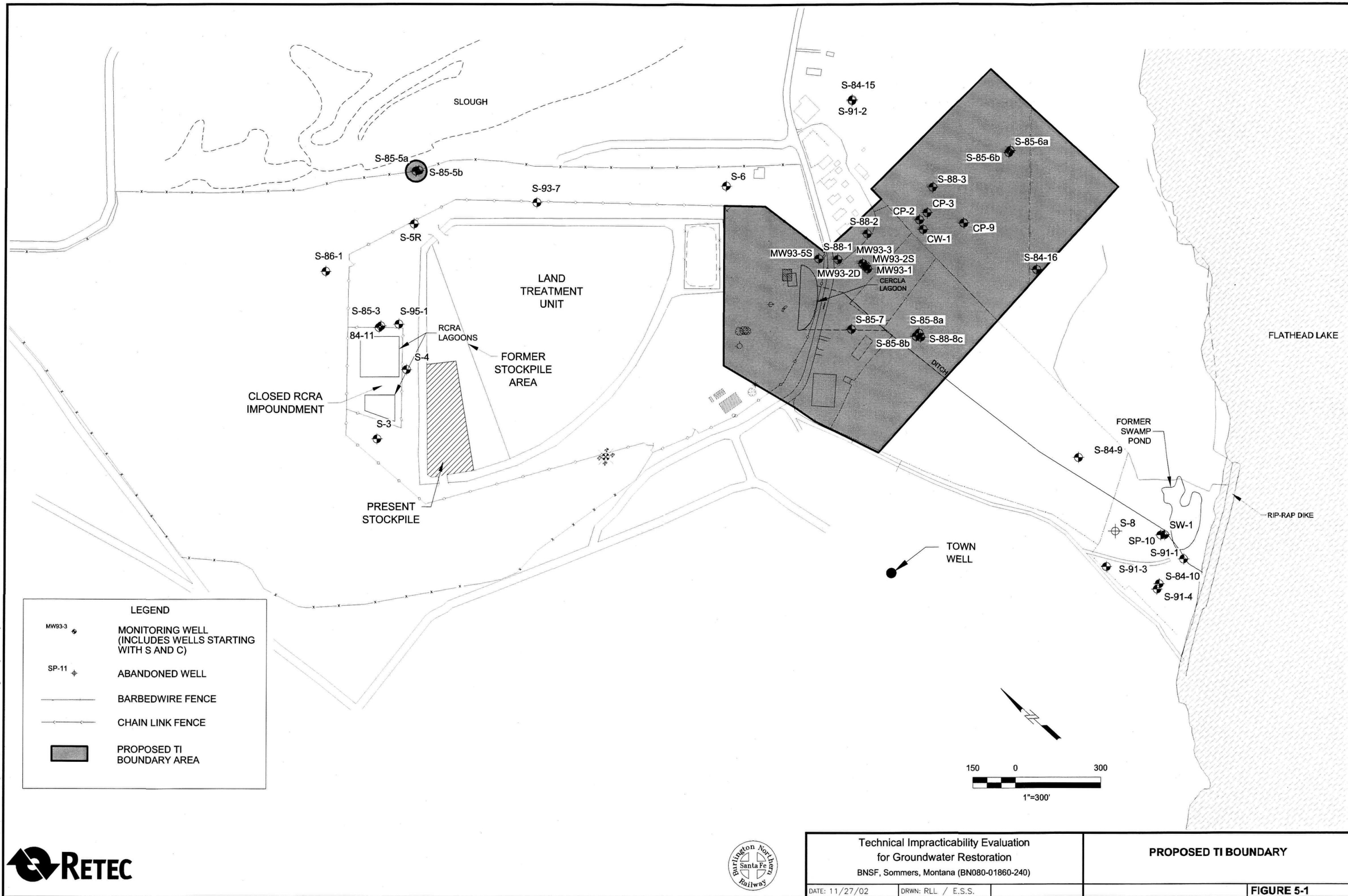
Technical Impracticability Evaluation
for Groundwater Restoration
BNSF, Sommers, Montana (BN080-01860-240)

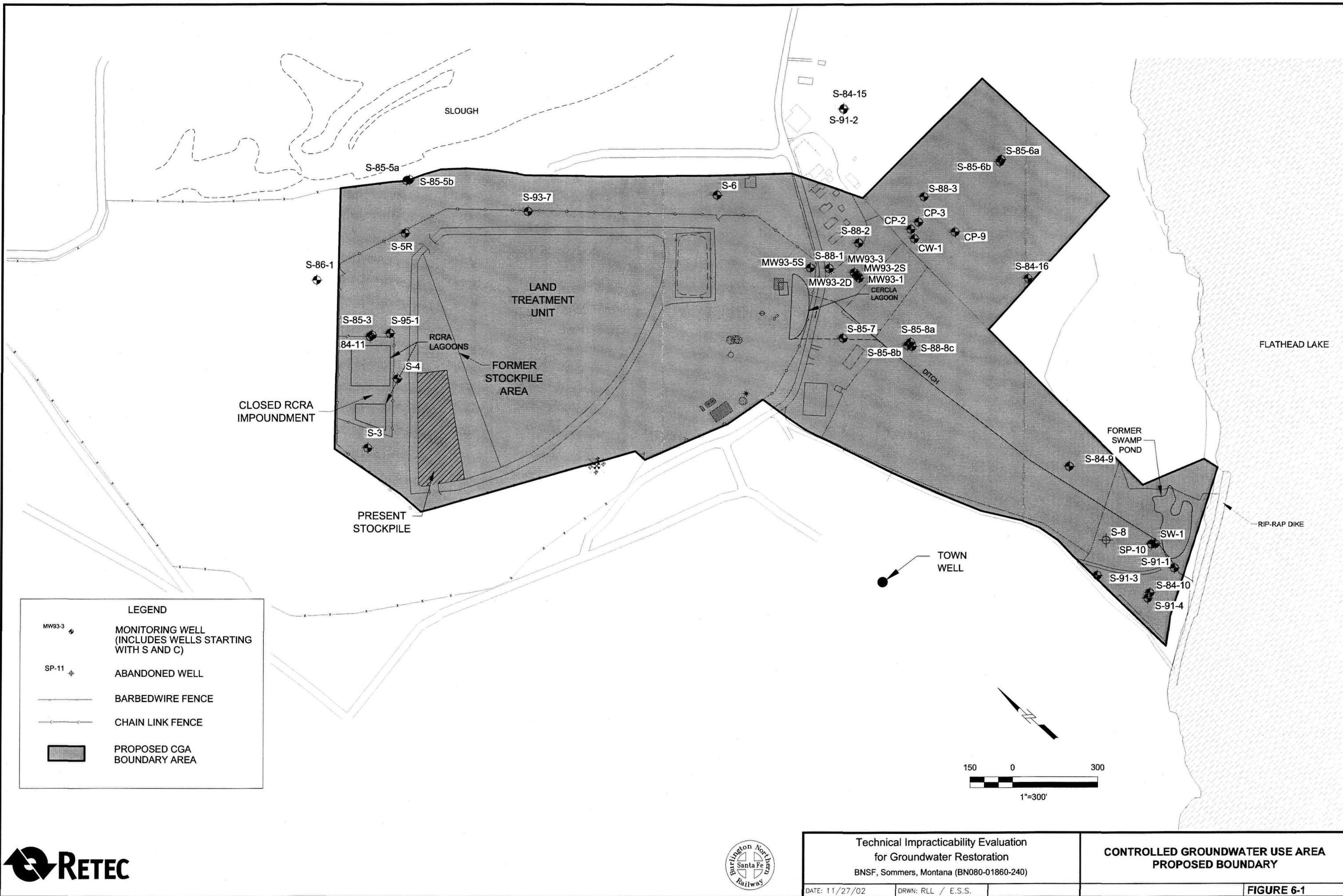
DATE: 11/26/02 DRWN: E.S.S./DEN

**GROUNDWATER TREATMENT
SYSTEM CAPTURE ZONE**

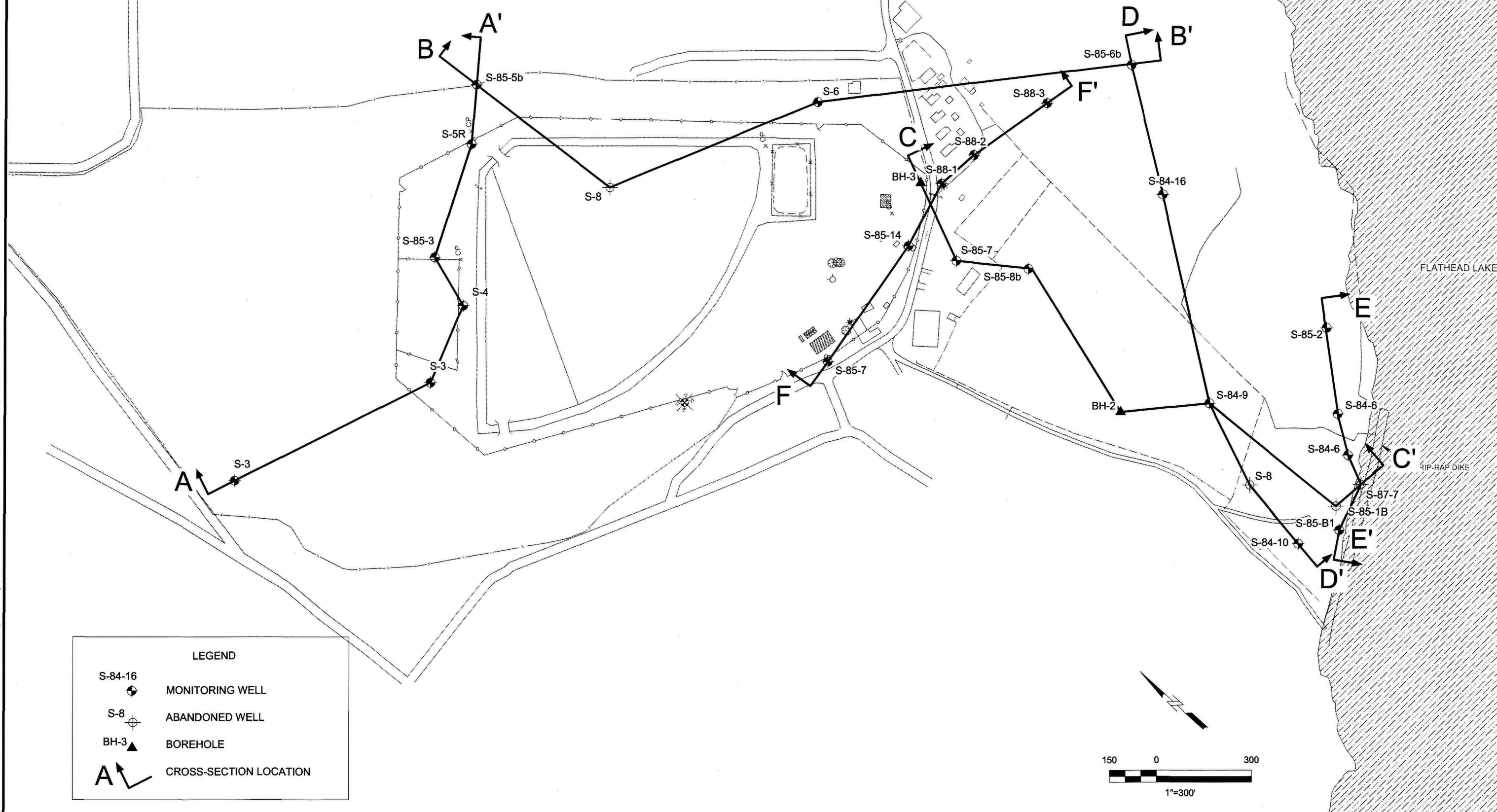
FIGURE 4-1

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Technical Impracticability Evaluation for Groundwater Restoration BNSF, Sommers, Montana (BN080-01860-240)		CROSS-SECTION LOCATION MAP BNSF - SOMMERS, MT
DATE: 11/26/02	DRWN: E.S.S./DEN	FIGURE A-1



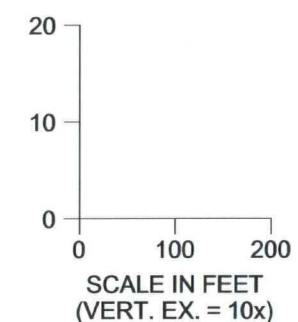
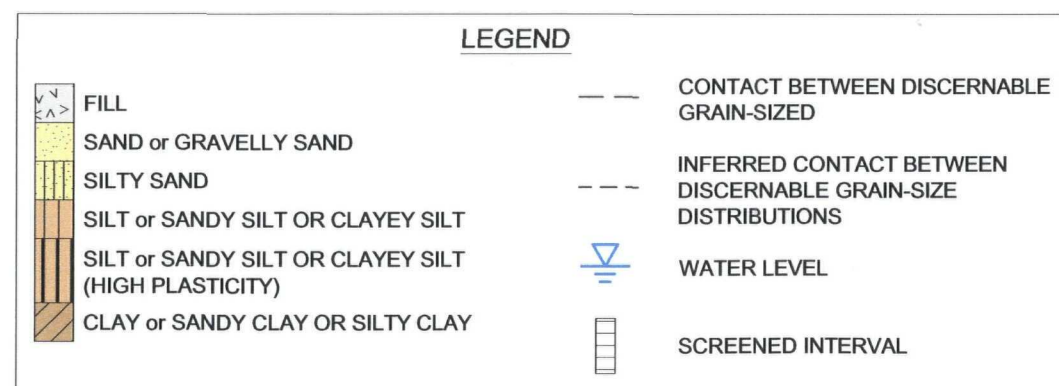
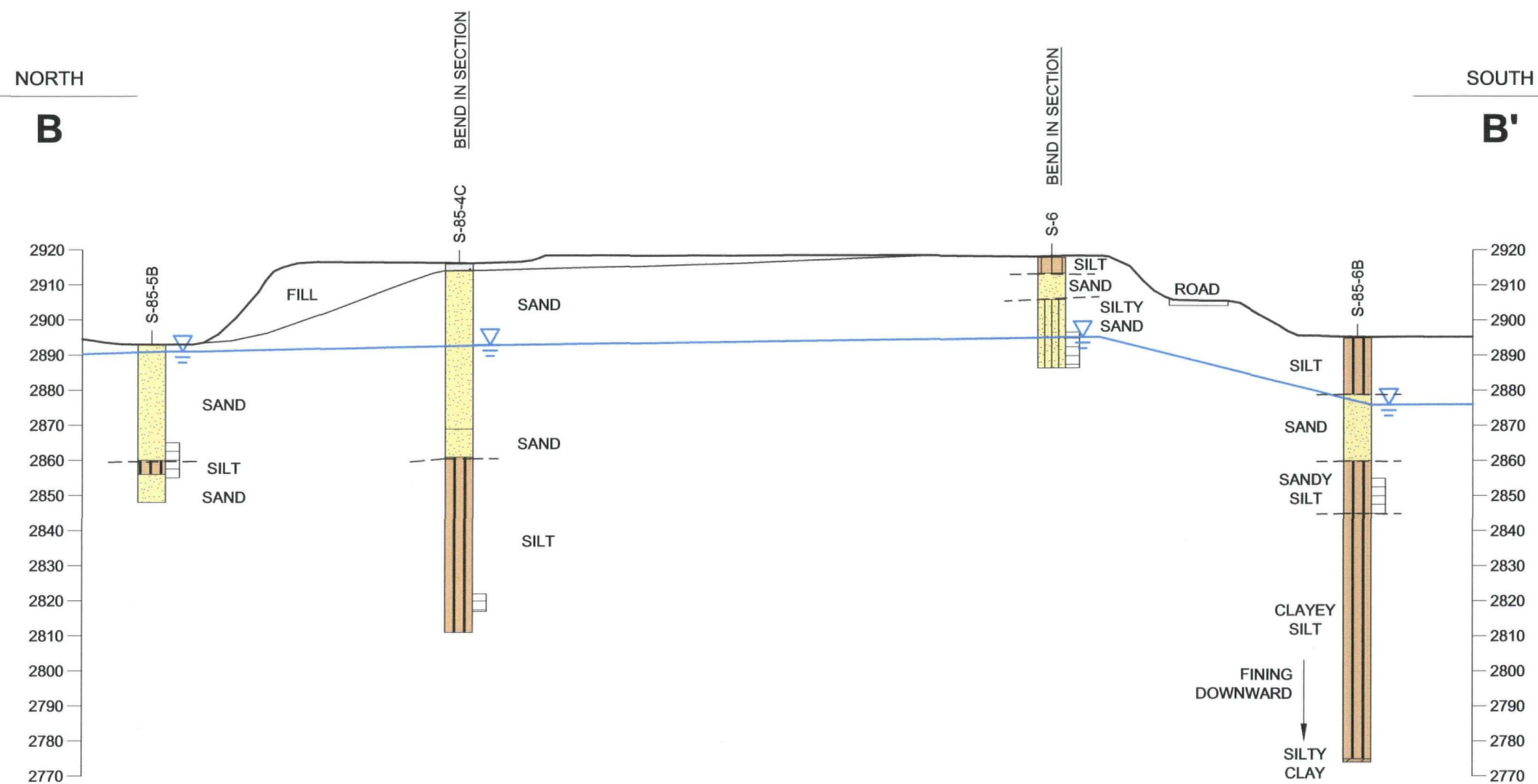
Technical Impracticability Evaluation
for Groundwater Restoration
BNSF, Sommers, Montana (BN080-01860-240)

DRWN: E.S.S./DEN

CROSS SECTION A-A'

FIGURE A-2

Fig. A-3 (01860) May 2001 Figures | SDW-TR-A-3.DWG Layout: Layout1 User: eschwartz Plotted: Nov 26, 2002 - 9:15am Xref's:



NOTE: REPRODUCED FROM RI/FS CROSS SECTIONS.



Technical Impracticability Evaluation
for Groundwater Restoration
BNSF, Sommers, Montana (BN080-01860-240)

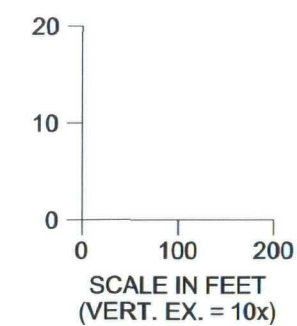
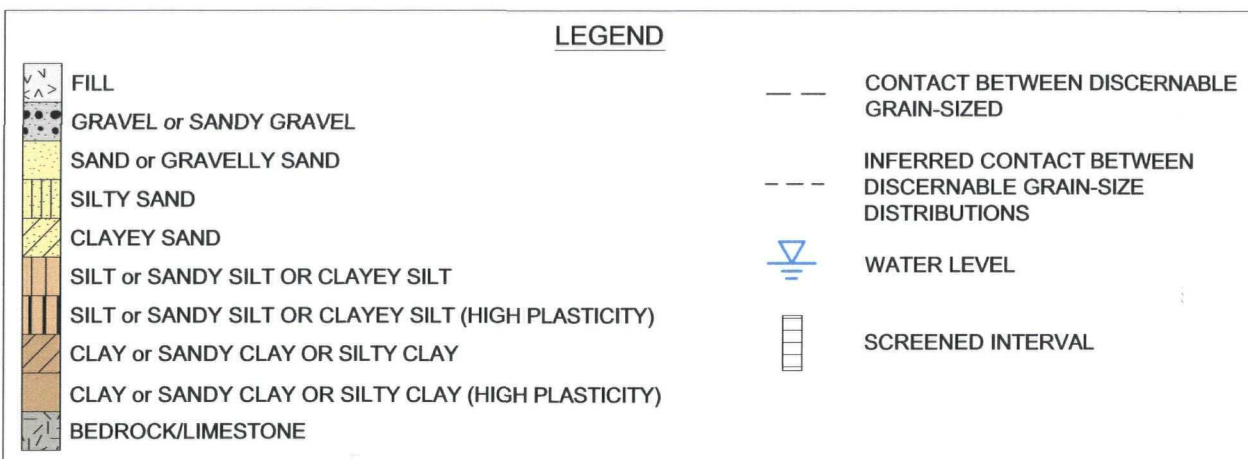
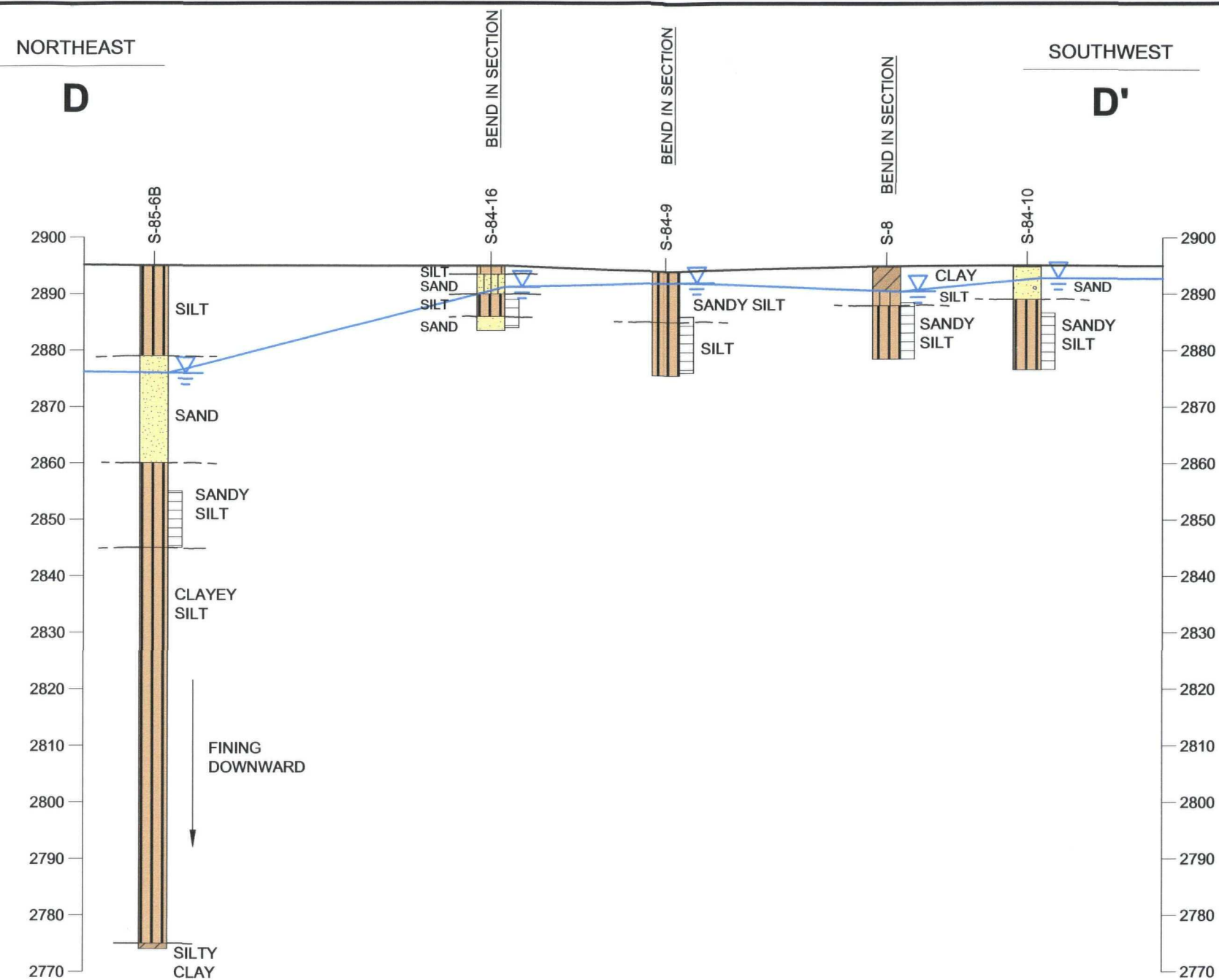
DATE: 11/26/02

DRWN: E.S.S./DEN

CROSS-SECTION B-B'

FIGURE A-3

File: A:\012610\101261010\Drawings\SOM-FIS-A-5.DWG Layout: Layout1 User: eschwartz Plotted: Nov 26, 2002 - 9:16am Xref's:



NOTE: REPRODUCED FROM RI/FS CROSS SECTIONS.



Technical Impracticability Evaluation
for Groundwater Restoration
BNSF, Sommers, Montana (BN080-01860-240)

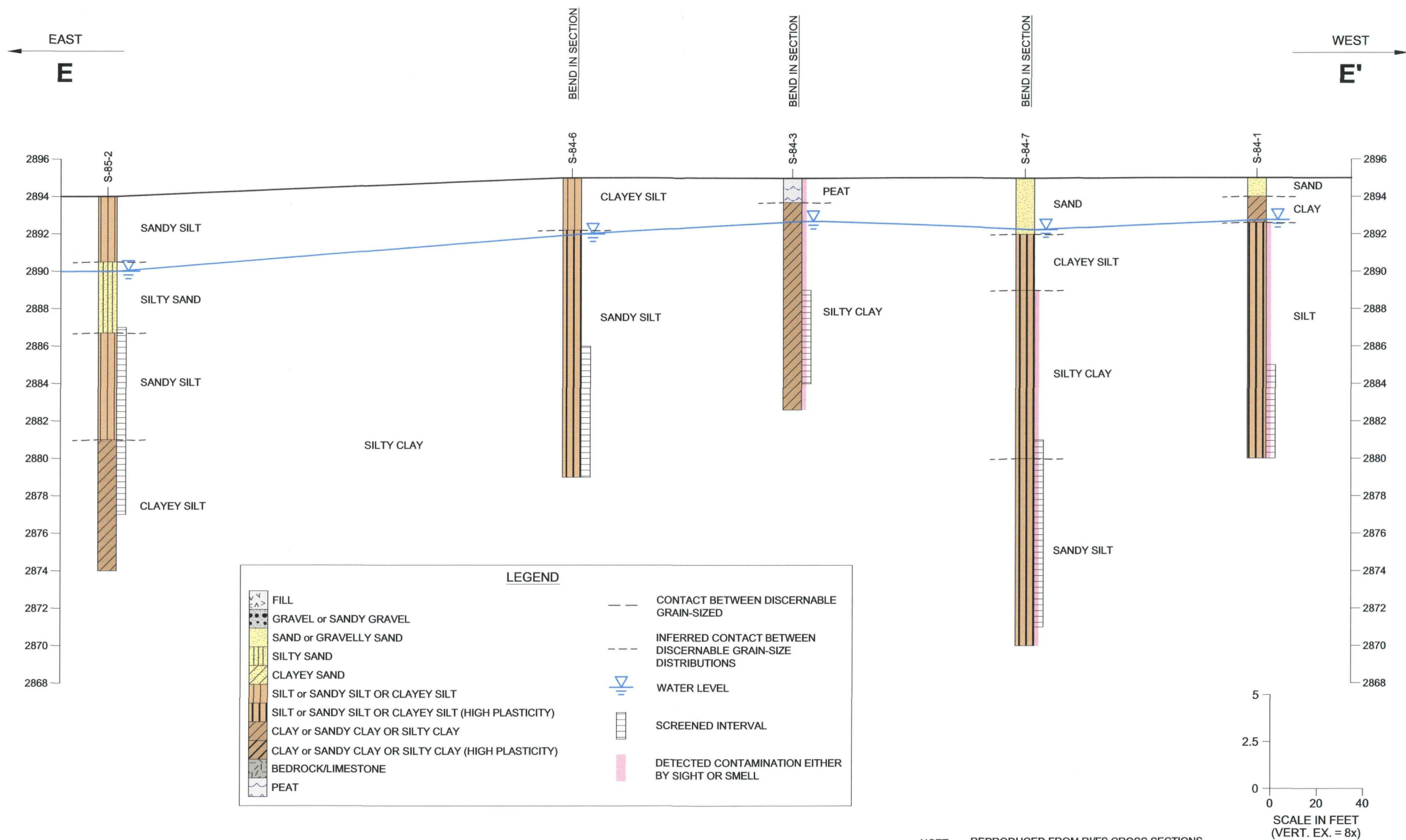
DATE: 11/26/02

DRWN: E.S.S./DEN

CROSS SECTION D-D'

FIGURE A-5

Fig. A-6 (11/26/02) May 2002 Figures (SOM-TIE A-6.DWG) Layout: Layout1 User: eschwartz Plotted: Nov 26, 2002 - 9:15am Xref's:



Technical Impracticability Evaluation
for Groundwater Restoration
BNSF, Sommers, Montana (BN080-01860-240)

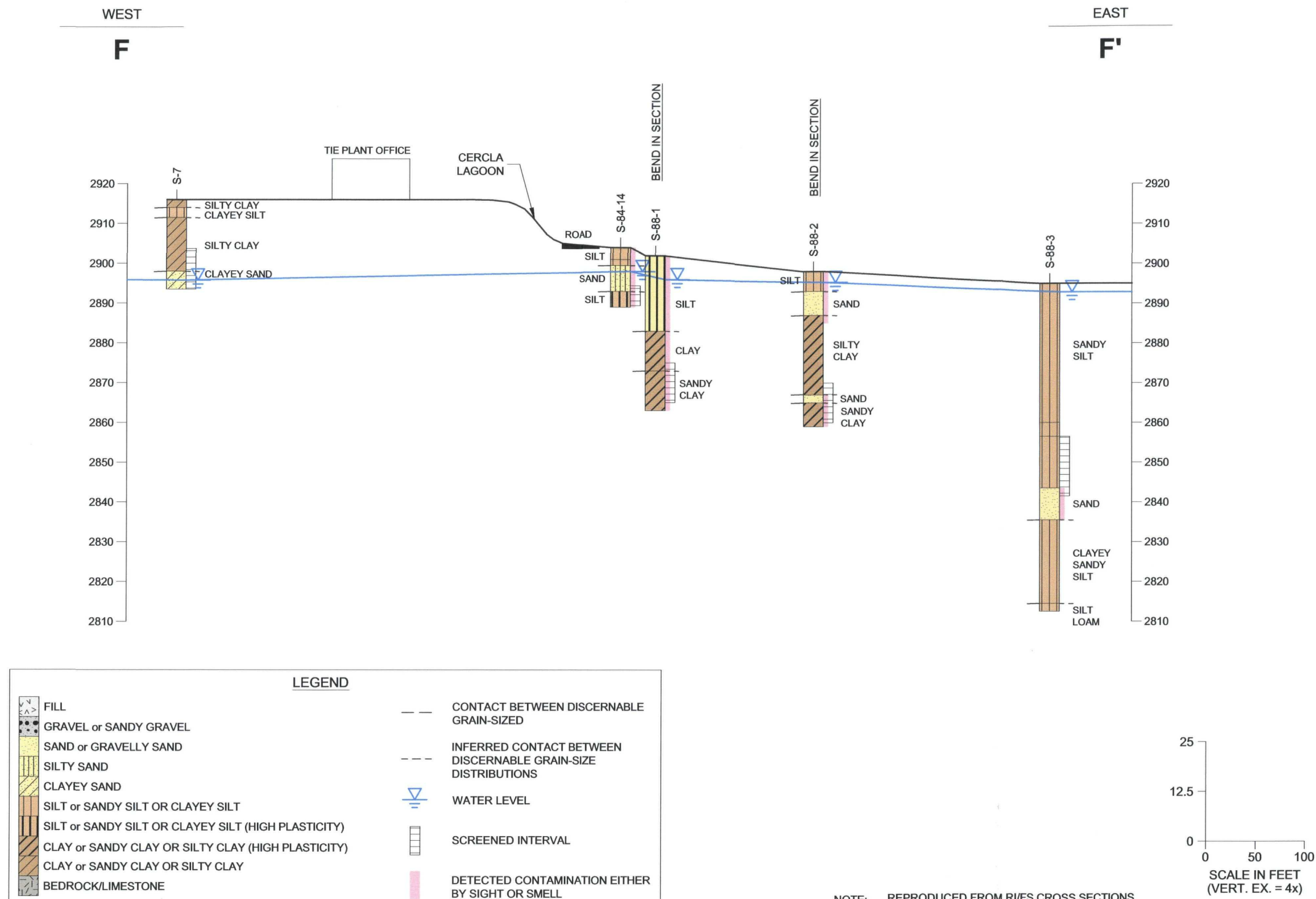
DATE: 11/26/02

DRWN: E.S.S./DEN

CROSS-SECTION E-E'

FIGURE A-6

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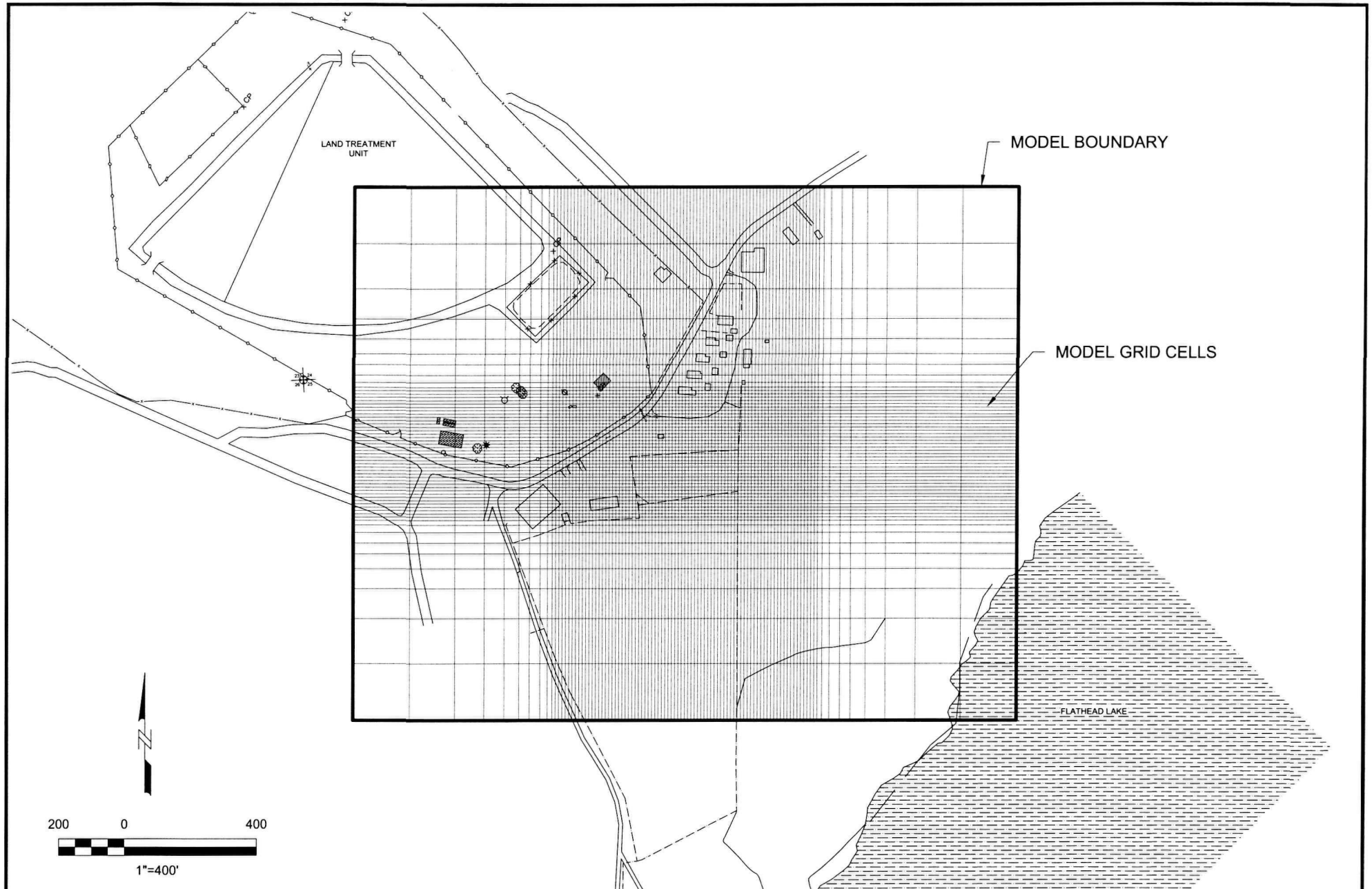
Technical Impracticability Evaluation
for Groundwater Restoration
BNSF, Sommers, Montana (BN080-01860-240)

DATE: 11/26/02

DRWN: E.S.S./DEN

CROSS-SECTION F-F'

FIGURE A-7



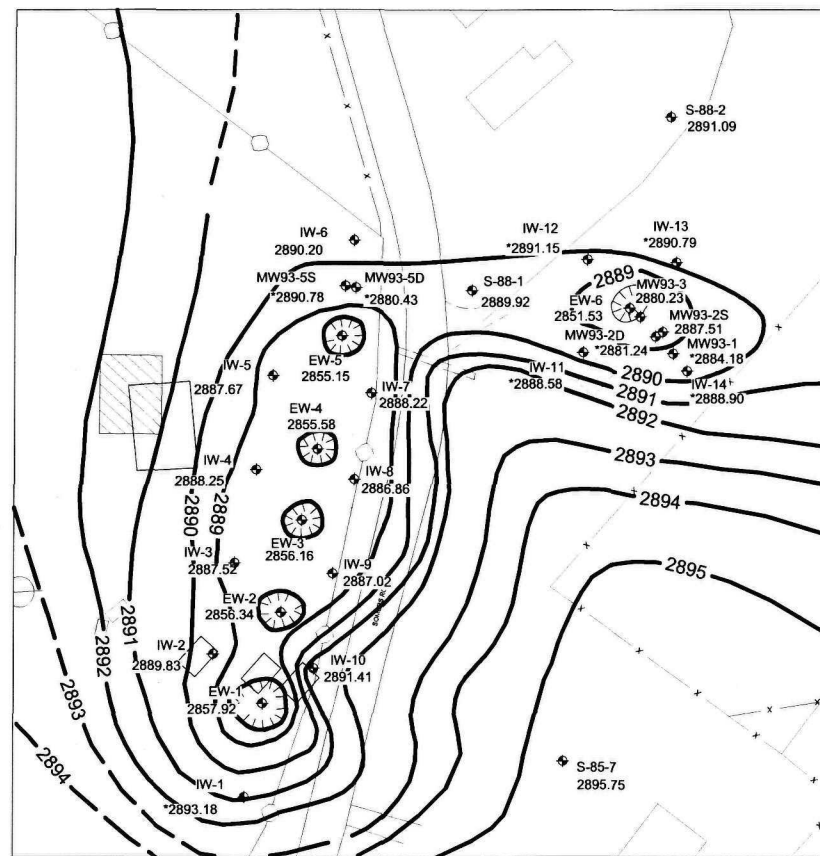
Technical Impracticability Evaluation
for Groundwater Restoration
BNSF, Sommers, Montana (BN080-01860-240)

MODEL GRID

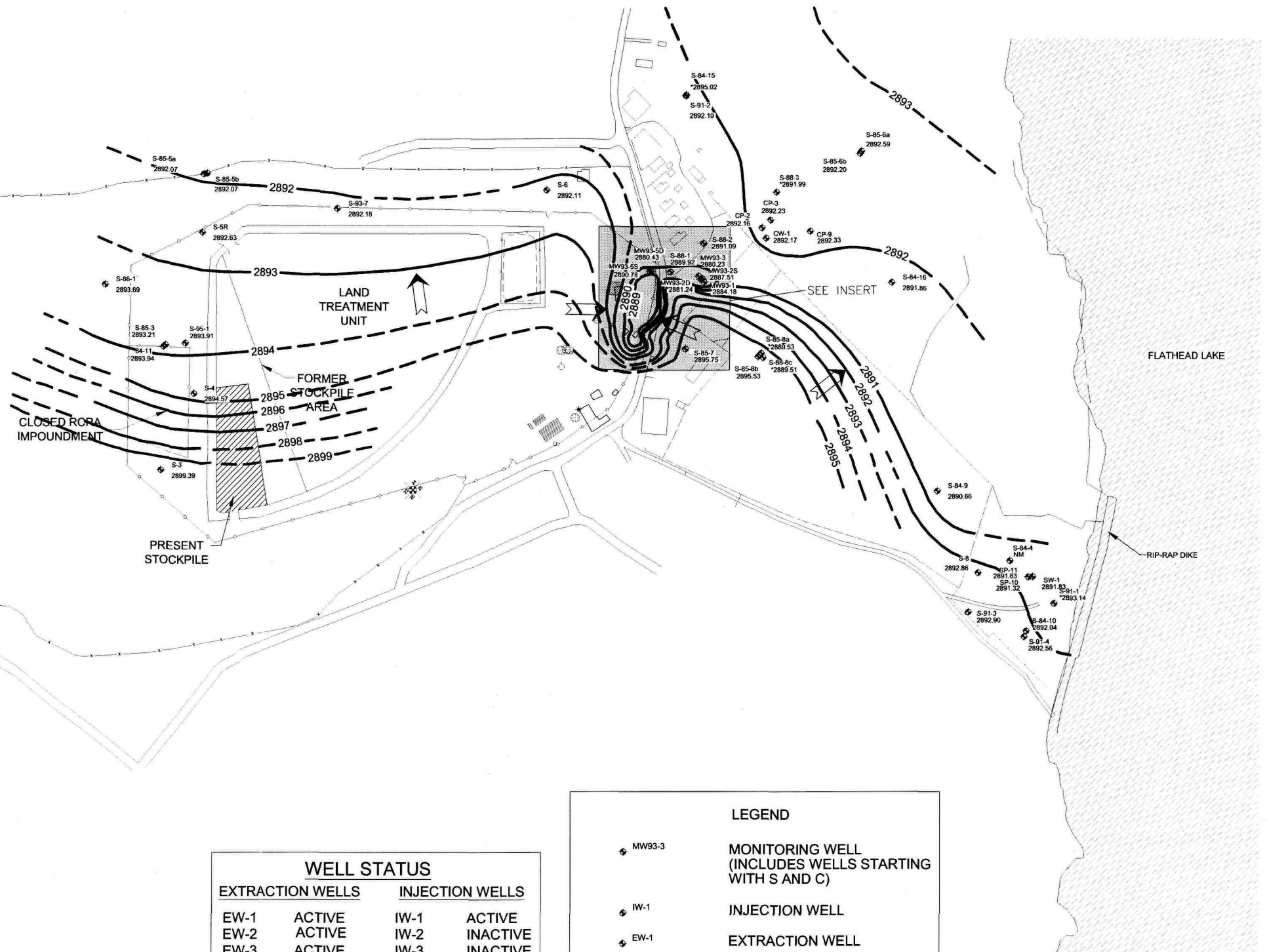
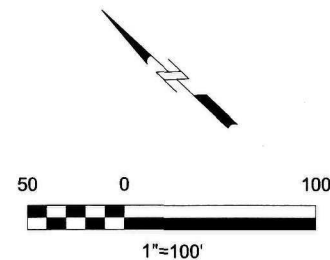
DATE: 11/26/02

DRWN:

FIGURE B-1

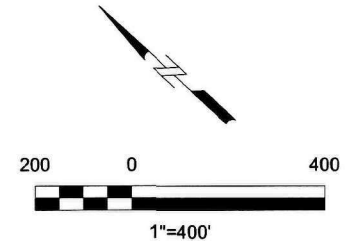


GROUNDWATER RECOVERY SYSTEM



WELL STATUS			
EXTRACTION WELLS		INJECTION WELLS	
EW-1	ACTIVE	IW-1	ACTIVE
EW-2	ACTIVE	IW-2	INACTIVE
EW-3	ACTIVE	IW-3	INACTIVE
EW-4	ACTIVE	IW-4	INACTIVE
EW-5	ACTIVE	IW-5	INACTIVE
EW-6	ACTIVE	IW-6	INACTIVE
		IW-7	INACTIVE
		IW-8	INACTIVE
		IW-9	INACTIVE
		IW-10	INACTIVE
		IW-11	ACTIVE
		IW-12	ACTIVE
		IW-13	ACTIVE
		IW-14	ACTIVE

LEGEND	
	MONITORING WELL (INCLUDES WELLS STARTING WITH S AND C)
	INJECTION WELL
	EXTRACTION WELL
	GROUNDWATER CONTOUR 1' INTERVAL (DASHED WHERE INFERRED)
	NOT MEASURED
	NOT USED TO CONTOUR
	GROUNDWATER FLOW DIRECTION
	GROUNDWATER RECOVERY SYSTEM AREA



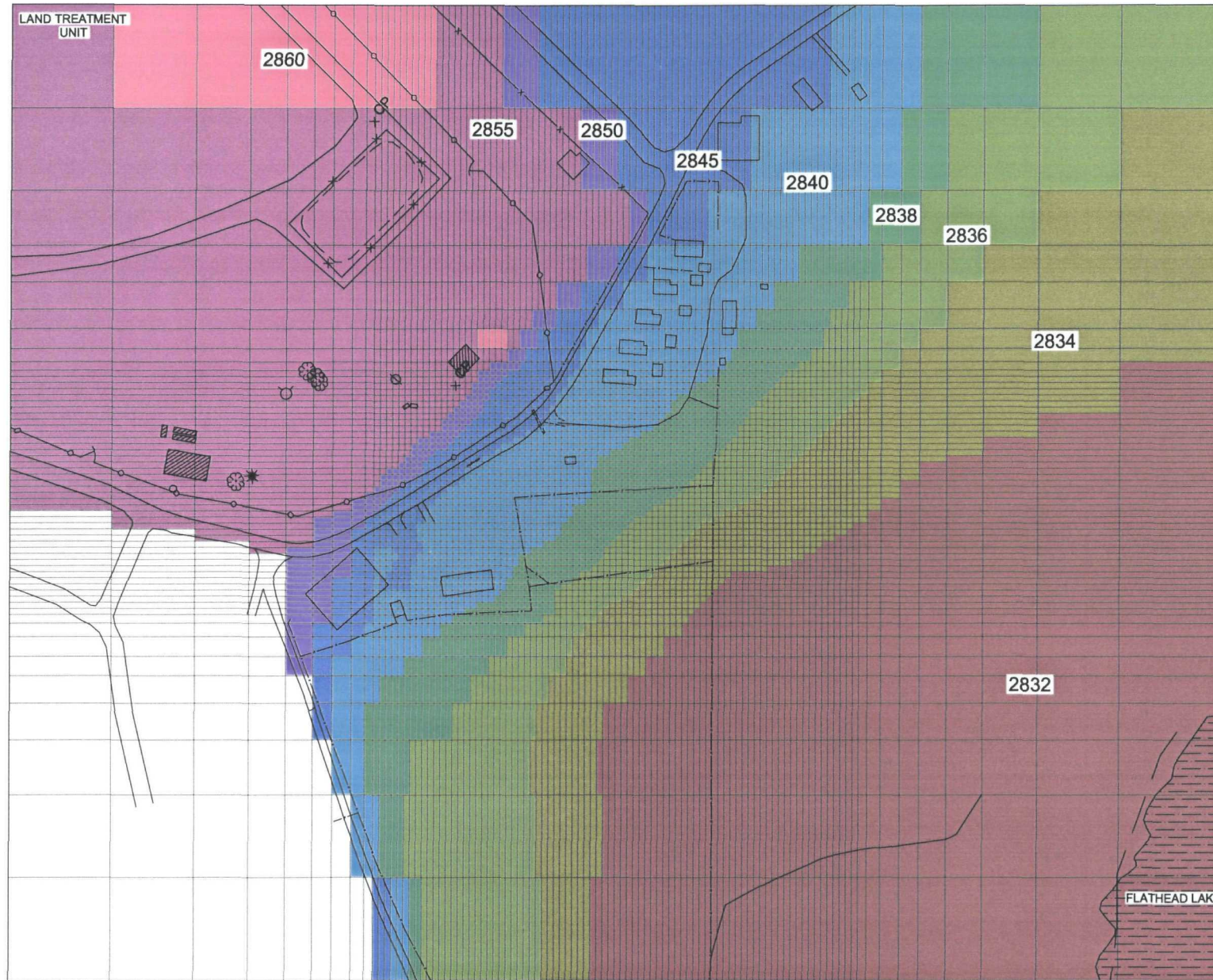
Technical Impracticability Evaluation
for Groundwater Restoration
BNSF, Sommers, Montana (BN080-01860-240)

GENERALIZED GROUNDWATER
POTENTIOMETRIC SURFACE MAP
APRIL 8, 1996

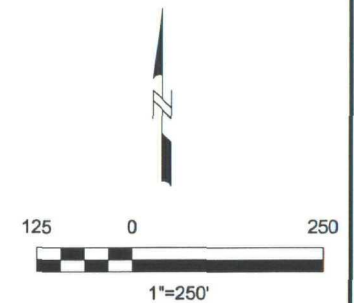
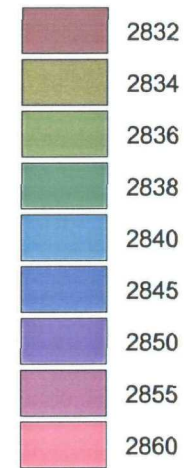
DATE: 11/26/02

DRWN: E.S.S./DEN

FIGURE B-2



ELEVATION (FT. AMSL)



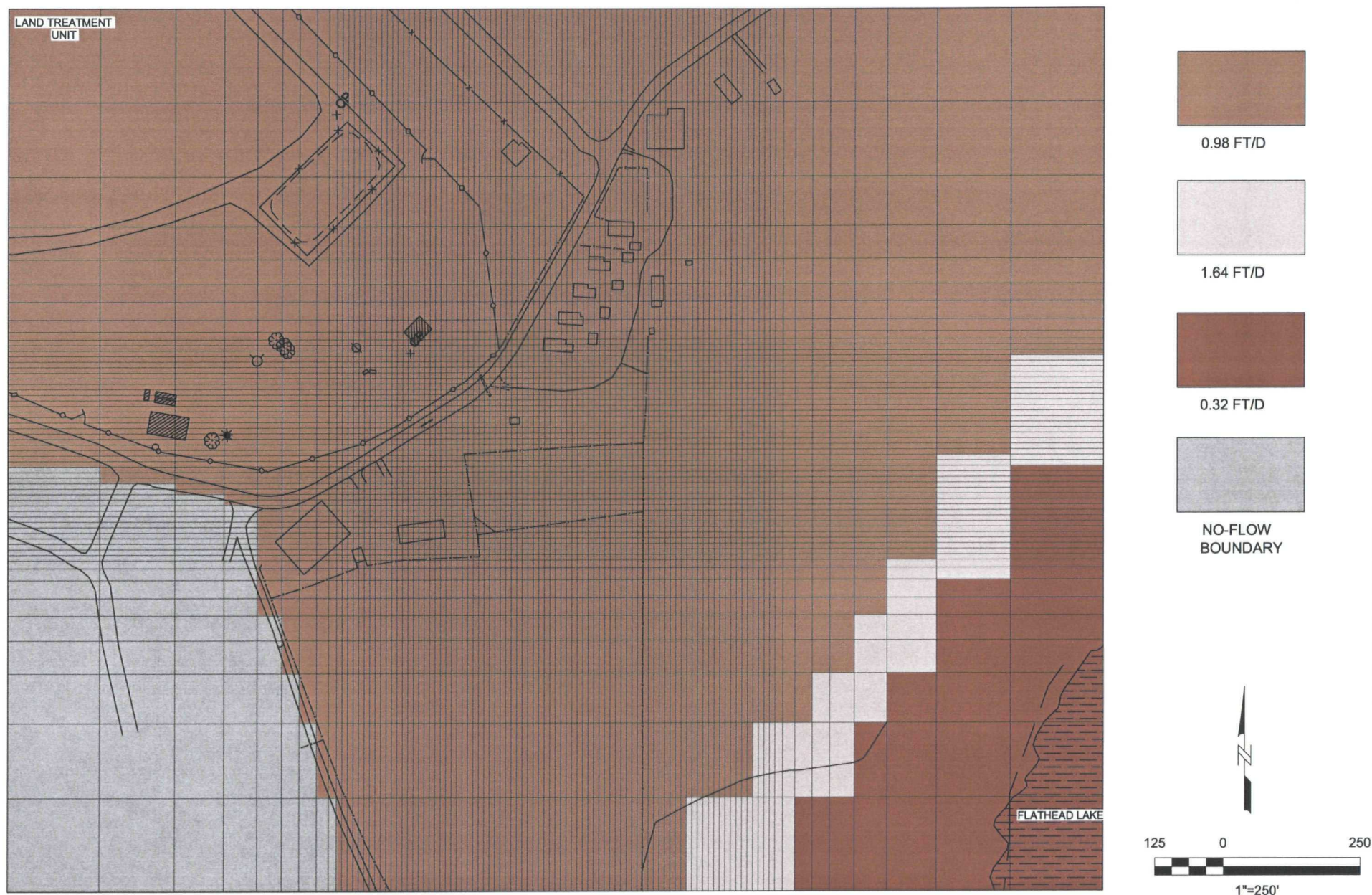
Technical Impracticability Evaluation
for Groundwater Restoration
BNSF, Sommers, Montana (BN080-01860-240)

DATE: 11/26/02

DRWN:

BOTTOM OF AQUIFER ELEVATION

FIGURE B-3



Technical Impracticability Evaluation
for Groundwater Restoration
BNSF, Sommers, Montana (BN080-01860-240)

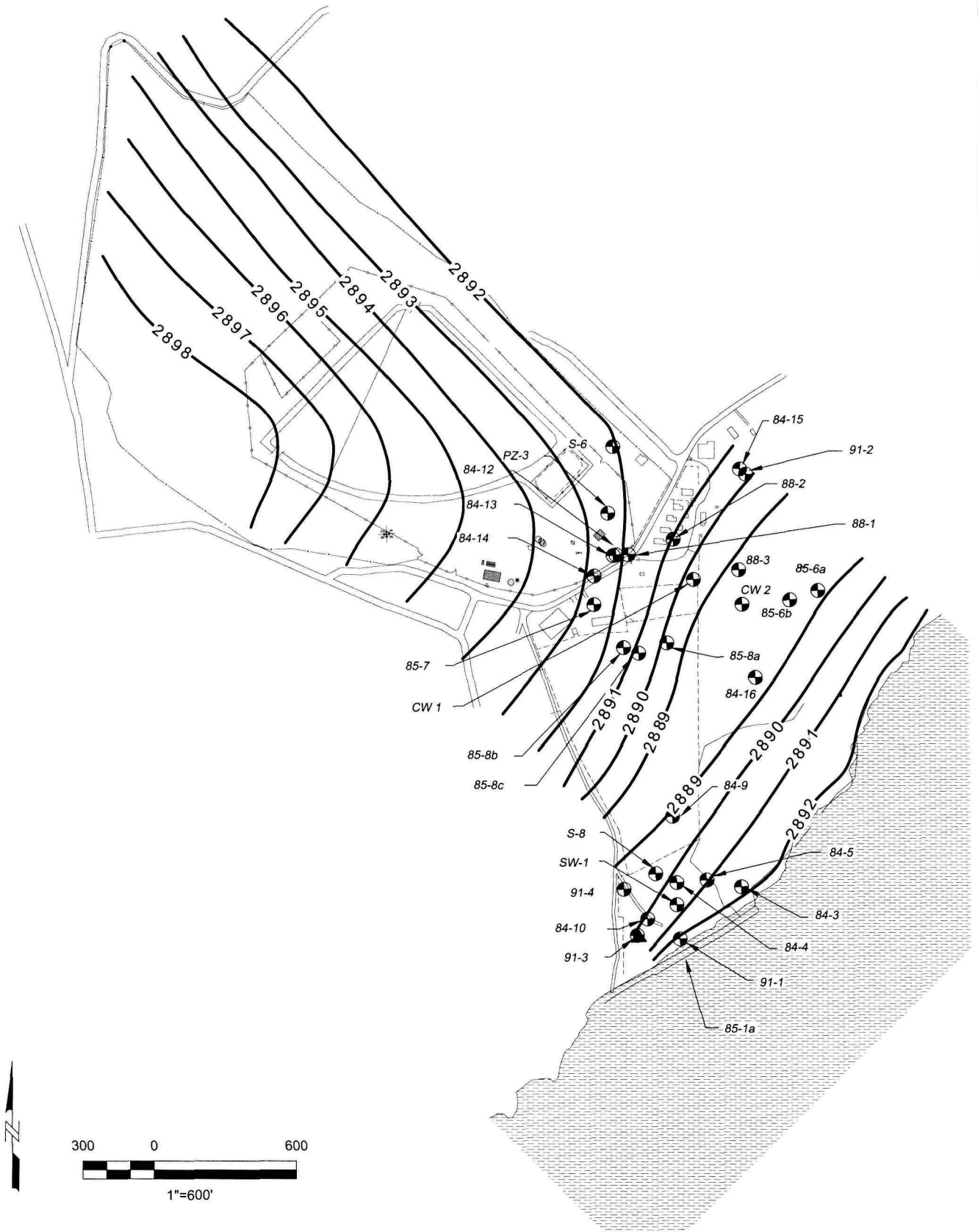
DATE: 11/26/02

DRWN:

HYDRAULIC CONDUCTIVITY DISTRIBUTION

FIGURE B-4

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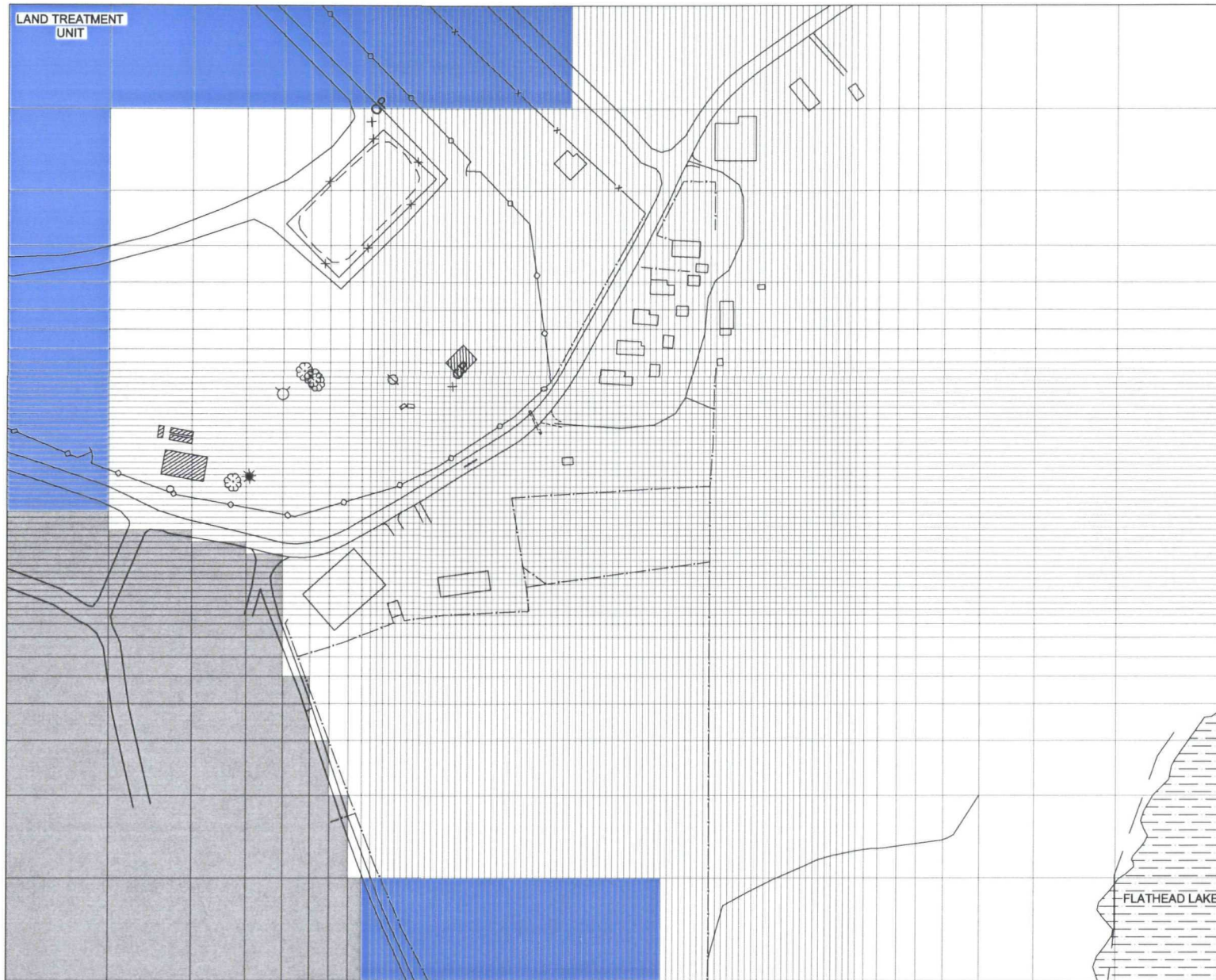


Technical Impracticability Evaluation
for Groundwater Restoration
BNSF, Sommers, Montana (BN080-01860-240)

POTENTIOMETRIC SURFACE MAP
BASED ON JAN. 13, 1992
WATER LEVELS

DATE: 11/26/02 DRWN: E.S.S./DEN

FIGURE B-5



Technical Impracticability Evaluation
for Groundwater Restoration
BNSF, Sommers, Montana (BN080-01860-240)

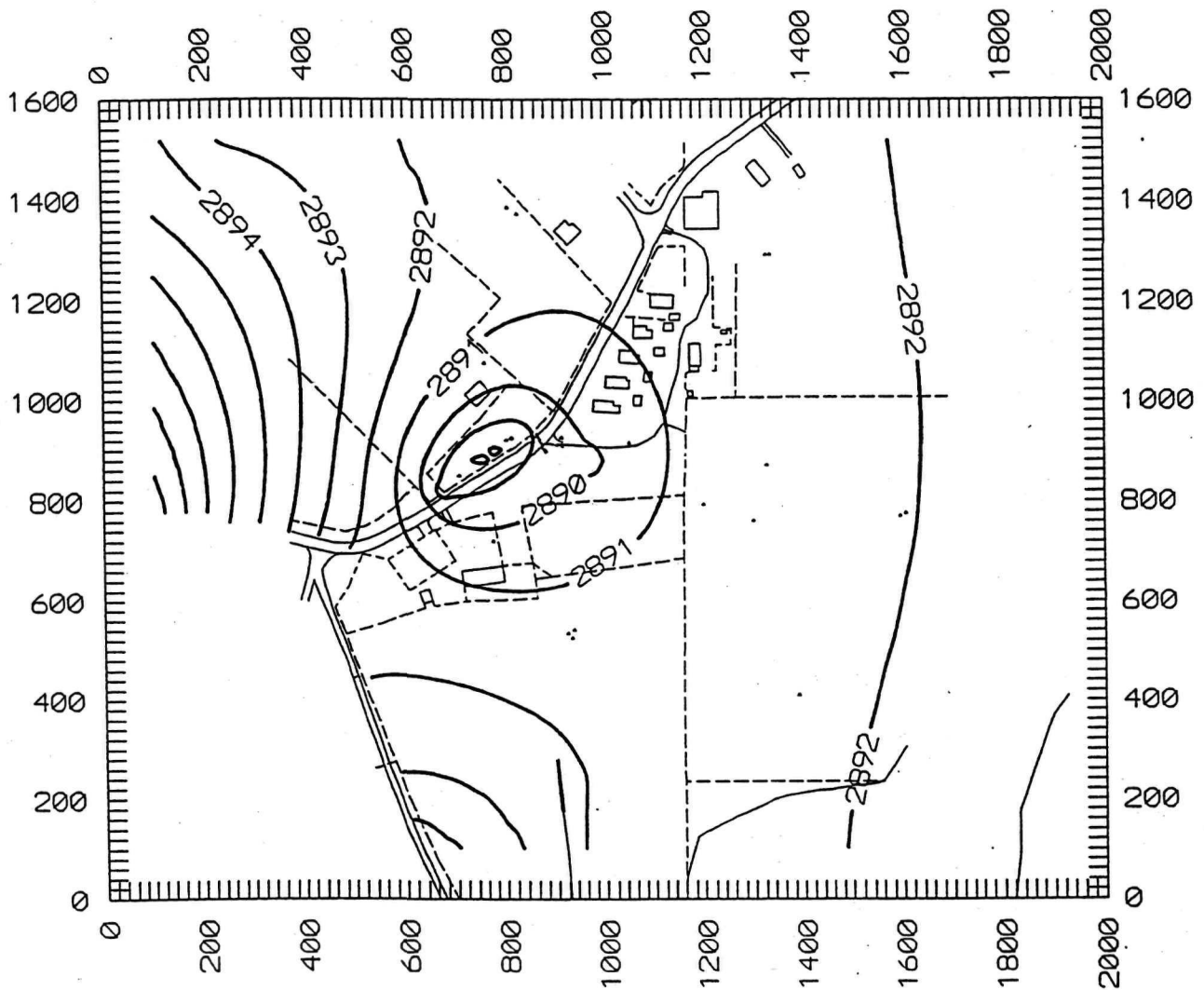
DATE: 11/27/02

DRWN:

BOUNDARY CONDITIONS

FIGURE B-6

BNRR Somers April 1996 Test #7



ZONE	HYDRAULIC CONDUCTIVITY
1	0.31FT/DAY (1.1 X 10 ⁻⁴ CM/SEC)
2	0.06FT/DAY
3	0.18FT/DAY

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Technical Impracticability Evaluation
for Groundwater Restoration
BNSF, Sommers, Montana (BN080-01860-240)

DATE: 11/26/02 DRWN: E.S.S./DEN

FLOW SIMULATION PHASE 1
TREATMENT SYSTEM
AREA OF INFLUENCE
APRIL 1997 TEST#7

FIGURE B-7

Appendix D

Protocol for Statistical Analysis of Groundwater Data

Statistical Analysis of Groundwater Data Through March 2000 Somers

Groundwater has been collected and analyzed from several monitoring wells at the site, for periods ranging from several months to 16 years.

The appropriate statistical analysis of the data from monitoring wells are outlined in the *Protocol for the Statistical Analysis of Groundwater Data*. The contaminants of concern are polycyclic aromatic hydrocarbons (PAH), of which naphthalene is generally the species in the largest concentration. The PAH data has also been reported as total polycyclic aromatic hydrocarbons (TPAH). TPAH was used to conduct the statistical analyses reported in this document. Historical TPAH concentrations are included in Table E-1, and range from June 1984 through March 2000.

Four general categories of monitoring well data can be identified at the site:

1. Wells in which there have been no detections of contamination
2. Wells in which there was in initial detection, which has decreased to non-detect
3. Wells in which there is sporadic data over the historical period
4. Wells in which there is sufficient data to conduct a statistical analysis

These categories are discussed in detail as follows.

Wells with no detections

The wells in which there were no PAH detections during the historical period are S-1, S-8, S-84-4, S-84-5, S-84-9, S-84-15, S-84-16, S-85-1b, S-85-2, S-85-4a/b/c, S-85-5b, S-85-6a, S-85-7, S-85-8a/b, S-86-1, S-91-3, S-91-4, S-95-1, SP-10, and the Swamp Pond well. Therefore, no statistical analysis has been provided for these wells.

Wells with an initial detection, decreasing to non-detect

This category includes wells S-2, S-3, S-4, S-5/S-5R, S-84-6, S-84-11, and TW-2. The TPAH concentrations within these wells were analyzed qualitatively, by observing the historical TPAH concentrations over time. This analysis has concluded that, although some level of contamination existed in these wells in the past, TPAH concentrations have decreased to, and remained, below the level of detection in the most recent sampling events. Therefore, no statistical analysis has been provided for these wells.

Wells with sporadic data

This category can be divided into two subgroups: wells which are mostly non-detect for PAHs, but which contain one or a few anomalous detections, and wells in which detections were observed, but have been discontinued for sampling and analysis. The first category includes wells S-84-10, S-85-6b, S-91-1, and S-93-7. These wells had one sampling event in which a low concentration of PAHs was reported, but which were followed by sampling events which were non-detect for PAHs. No statistical analysis has been provided for these wells.

The second category includes wells S-84-1, S-84-3, S-84-14, S-93-5D, SP-11, and TW-1. These wells contained few detected values in the historical data set, but were discontinued for sampling and analysis. These wells were not evaluated statistically.

Wells with detections of PAHs

This category includes wells S-6, S-85-3, S-85-5a, S-88-1, S-88-2, S-88-3, S-93-2S, and S-93-2D.

Well S-85-3 was non-detect for PAHs throughout the historical period, however, there was a small detection (6 ug/L) during the March 1999 sampling event. This well was non-detect for TPAH during the September 1999 and March 2000 sampling periods, indicating that the detection in March 1999 is anomalous.

Well S-85-5a is similar to well S-85-3, except that there were detections of PAHs in August 1996, September 1998, and March 1999 (with a non-detect in December 1998). The detections were low (1.3 to 7.3 ug/L). This well was non-detect for TPAH during the June 1999, September 1999, December 1999, and March 2000 sampling periods, indicating that the low TPAH concentrations that were previously detected were anomalous.

Well S-6 was non-detect for PAHs throughout most of the historical period, however, there were detections of PAHs from March 1998 through March 2000. The detection in March 1998 was 3 ug/L, increasing to 570 ug/L in September 1998. Detections between September 1998 and March 2000 ranged from 320 to 600 ug/L. The data from March 1998 to March 2000 was analyzed statistically.

The S-88-1, S-88-2 and S-88-3 data consisted of a cluster of analyses conducted in the summer of 1988, followed by semi-annual data collected from August 1996 through March 1999. The S-88-1 data is sporadic, with results reported for August 1996, March 1998, September 1998, and March 1999; however, there were detections at high concentrations (6,901 to 12,381 ug/L) in September 1999, December 1999, and March 2000. This data is not sufficient to conduct a statistical analysis, and more data will be required to proceed. Wells S-88-2 and S-88-3 contained more complete data, and were analyzed statistically.

The S-93-2S and S-93-2D data consisted of quarterly analyses spanning the historical period from August 1994 through March 2000.

Statistical Analysis

The data for wells S-6, S-88-2, S-88-3, S-93-2S, and S-93-2D were tested for seasonality using the Kruskal-Wallis test at the 5% significance level. The Kruskal-Wallis test is a non-parametric test which determines differences in groupings of data. The existence of a significant trend was determined using the Mann-Kendall trend analysis, which is a non-parametric procedure. Results are reported at the 5% level of significance. The Sen=s Slope Estimator was used to determine the rate of change over time of TPAH concentrations in each well. The slope of the concentrations was only valid if the Mann-Kendall test was significant. The Kruskal-Wallis test for seasonality and Mann-Kendall test for trend were determined using the statistical computer program WQStat Plus (IDT, 1998). All non-detect values were set to one-half the detection limit prior to conducting the statistical analyses.

Results

The results of the statistical analyses for wells S-6, S-88-2, S-88-3, S-93-2S, and S-93-2D are discussed in this section.

Well S-6

The historical data used for the statistical analyses of Well S-6 are presented in Table D-1 and Figure D-1. There was a low detection of TPAH in March 1998 (3 ug/L) followed by high detections starting in September 1998. The data used for conducting a trend analysis ranged from September 1998 through March 2000. The Kruskal-Wallis seasonality test indicated no seasonality, however, there were not enough seasons of data to enable an accurate test. The Mann-Kendall trend test indicated no significant trend. The sudden increase in TPAH during the September 1998 sampling period, and subsequent high TPAH values, are unexplained. This well will be monitored further to assess any trend in the data over time.

Wells S-88-2 and S-88-3

The historical data used for the statistical analyses are presented in Table D-2 and Figure D-2. These data do not include the 1988 data cluster, but include the period of August 1996 through March 2000. The data was not evenly distributed among seasons for the historical period, with one sampling event in 1996, two in 1997, and three in 1998.

The Kruskal-Wallis seasonality test indicated no seasonal effects of TPAH concentrations for either of the two wells. The Mann-Kendall trend test indicated no significant trend at the 5% level for well S-88-2, but a significant downward trend of 132 ug TPAH/L/year for well S-88-3. A graphical presentation of the data indicates that the TPAH concentrations are decreasing in both of the S-88 wells. Further sampling results are needed to better assess the data trend.

Wells S-93-2S and S-93-2D

The historical data used for the statistical analyses are presented in Table D-3 and Figure D-3. These data were collected from the period August 1994 through March 2000. The Kruskal-Wallis seasonality test indicated no seasonality at the 5% significance level for either well. The Mann-Kendall trend test indicated no significant trend for well 93-2S, but an increase in TPAH for well 93-2D. The significant increase in TPAH in well 93-2D appears to be due to the abnormally high TPAH value reported in June 1999 (2,711 ug/L). Since this time, the TPAH concentrations in both wells have dropped to within their normal ranges for these wells. Therefore, the statistical increase in TPAH in well 93-2D is considered to be an anomaly, as it appears that there is no apparent trend in this well.

Conclusions

Five monitoring wells (S-6, S-88-2, S-88-3, S-93-2S, and S-93-2D) were tested for seasonality and trend in TPAH concentrations. There was a statistically significant downward trend in TPAH in well S-88-3, and statistically significant upward trend in well 93-2D. There was no evidence of a trend in the TPAH concentrations in any of the other wells. The downward trend in well S-88-3 is indicative of TPAH concentration in both of the S-88 wells which were analyzed. The upward trend in well 93-2D appears to be a result of an unusually high TPAH value in June 1999. The TPAH concentrations in this well have decreased to within the normal historical range since that sampling period.

References

IDT, 1998. WQSTAT PLUS. User=s Guide. Intelligent Decision Technologies, LTD. Longmont, CO.

Table D-1
Statistical Analysis of Historical TPAH Data
Well S-6
BNSF - Somers, MT

Sample Date	TPAH (ug/L) Well S-6
Mar-98	3
Jun-98	
Sep-98	570
Dec-98	480
Mar-99	360
Jun-99	320
Sep-99	600
Dec-99	460
Mar-00	530

Kruskal-Wallis Seasonality	
test statistic	0.300
critical statistic	3.241
significant at %5 level?	No

Mann-Kendall Trend	
test statistic	-1
critical statistic	-15
significant at %5 level?	No

Sen's slope estimator (ug	-20
---------------------------	-----

Notes:

Sen's slope estimator not applicable due to non-significance of trend
 Bold values indicate exceedance of TPAH clean-up goal of 40 ug/L.

Figure D-1. TPAH in Well S-6

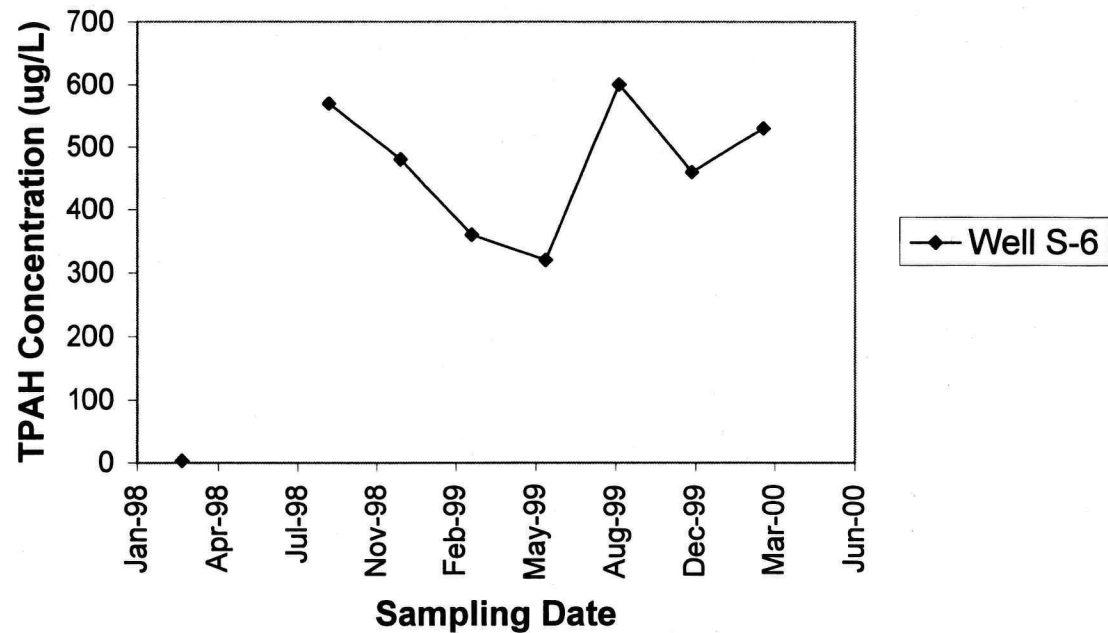


Table D-2
Statistical Analysis of Historical TPAH Data
Voluntary Wells S-88-2 and S-88-3
BNSF - Somers, MT

Sample Date	TPAH (ug/L)	
	Well S-88-2	Well S-88-3
Aug-96	1377	400
May-97	431	380
Sep-97	465	350
Mar-98	1361	490
Sep-98	477.7	360
Dec-98	698	310
Mar-99	331	140
Jun-99	159	100
Sep-99	881	0
Dec-99	727	40
Mar-00	59	54

Notes:

Kruskal-Wallis Seasonality

test statistic	0.003	0.3
critical statistic	3.241	3.241
significant at %5 level?	No	No

Mann-Kendall Trend

test statistic	-15	-41
critical statistic	-27	-27
significant at %5 level?	No	Down

Sen's slope estimator (ug	-162	-132
---------------------------	------	------

Notes:

Sen's slope estimator not applicable for S-88-2 due to non-significance of trend
 Bold values indicate exceedance of TPAH clean-up goal of 40 ug/L.

Figure D-2. TPAH in Wells S-88-2 and S-88-3

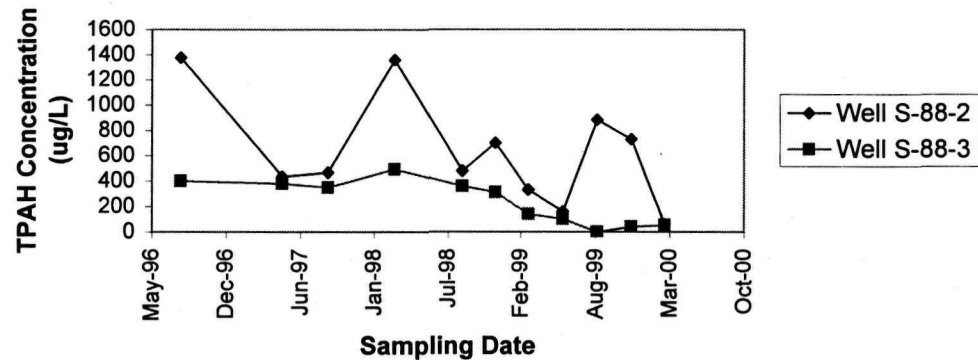


Table D-3
Statistical Analysis of Historical TPAH Data
Treatment Area Wells S-93-2S and S-93-2D
BNSF - Somers, MT

Sample Date	TPAH (ug/L)	
	Well 93-2S	Well 93-2D
Aug-94	3915	2
Nov-94	1568	2
Mar-95	9786	1300
May-95	900.9	33
Sep-95	1085	5.2
Dec-95	1079	4.4
Apr-96	1044	2
Jun-96	5367	1
Aug-96	868.3	191.2
Dec-96	1539	34.9
May-97	401	13
Jun-97	911	<1.0
Sep-97	2561	7.6
Dec-97	609	32
Mar-98	1155	14
Jun-98	1267	24
Sep-98	2000	392
Dec-98	411.5	21
Mar-99	2912	503
Jun-99	4058	2711
Sep-99	1922	101
Dec-99	1397	65
Mar-00	2387	42

Kruskal-Wallis Seasonality

test statistic	0.061	0.126
critical statistic	3.241	3.241
significant at %5 level?	No	No

Mann-Kendall Trend

test statistic	9	88
critical statistic	76	76
significant at %5 level?	No	Up

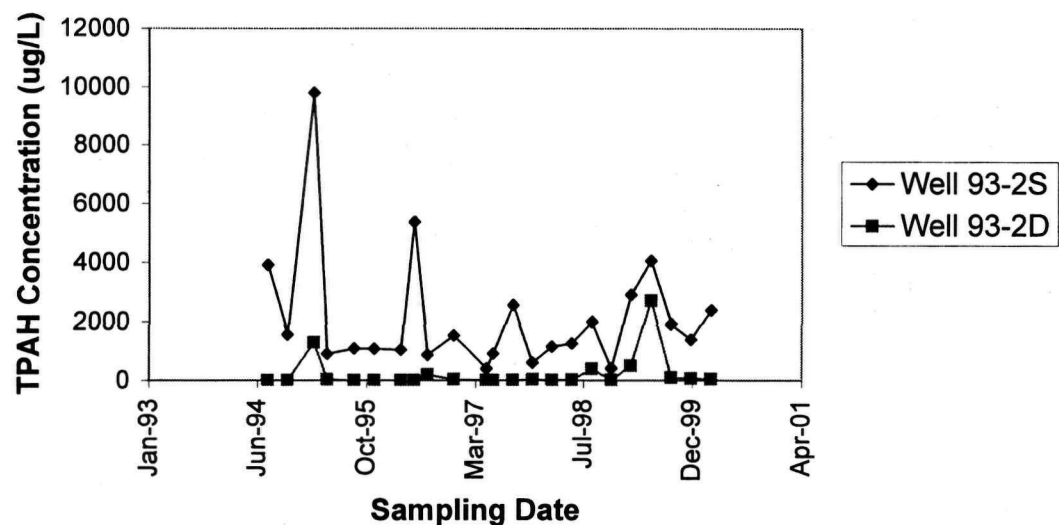
Sen's slope estimator (ug

33.8	9.3
------	-----

Notes:

Sen's slope estimator not applicable for S-93-2S due to non-significance of trend
 Bold values indicate exceedance of TPAH clean-up goal of 40 ug/L.

Figure D-3. TPAH in Wells 93-2S and 93-2D



Appendix E

Total PAH Concentrations 1984 - 2000

Table E-1
Total PAH Concentrations (ug/L)
Historical Data (1984-2000)
BNSF Tie Plant - Somers, MT

Well Number	June 1984	July 1984	Feb 1986	June 1986	Nov 1986	March 1987	June 1987	Oct 1987	Dec 1987
S-1	---	---	---	<1	<1	---	---	---	---
S-2	116	0.151	<5	<1	<1	---	---	---	---
*S-3 / S-3R	1.172	0.479	<5	<1	<1	<1	<1	<1	<2
S-4	1.952	1.102	<5	<1	<1	<1	<1	<1	<2
*S-5 / S-5R	1.355	0.571	<5	<1	<1	<1	<1	<1	<2
S-6	---	---	<5	<1	<1	---	---	---	---
S-8	---	---	---	<1	<1	---	---	---	---
S-84-1	---	---	17,250	---	3,900	---	---	---	---
S-84-3	---	---	18,280	---	---	---	---	---	---
S-84-4	---	---	---	<1	<1	---	---	---	---
S-84-5	---	---	---	<1	<1	---	---	---	---
S-84-6	---	---	---	30	<1	---	---	---	---
S-84-9	---	---	---	<1	<1	---	---	---	---
S-84-10	---	---	---	<1	<1	---	---	---	---
S-84-11	188	154	10	<1	<1	18	44	300	1,200
S-84-14	---	---	---	---	---	---	---	---	---
S-84-15	---	---	---	<2	<1	---	---	---	---
S-84-16	---	---	---	<1	<1	---	---	---	---
S-85-1b	---	---	---	<1	<1	---	---	---	---
S-85-2	---	---	---	<1	<1	---	---	---	---
S-85-3	---	---	<5	<1	<1	<1	<1	<1	<2
S-85-4a	---	---	<5	<1	<1	---	<1	---	<2
S-85-4b	---	---	<5	<2	<1	<1	<1	<1	<2
S-85-4c	---	---	<5	<1	<1	<1	<1	<1	<2
S-85-5a	---	---	<5	<1	<1	<1	<1	<1	<2
S-85-5b	---	---	<5	<1	<1	<1	<1	<1	<2
S-85-6a	---	---	---	<1	<1	---	---	---	---
S-85-6b	---	---	---	<1	<1	---	---	---	---
S-85-7	---	---	<5	<1	<1	---	---	---	---
S-85-8a	---	---	<5	<1	<1	---	---	---	---
S-85-8b	---	---	---	<1	<1	---	---	---	---
S-86-1	---	---	---	---	<1	<1	<1	<1	<3
S-88-1	---	---	---	---	---	---	---	---	---
S-88-2	---	---	---	---	---	---	---	---	---
S-88-3	---	---	---	---	---	---	---	---	---
S-91-1	---	---	---	---	---	---	---	---	---
S-91-3	---	---	---	---	---	---	---	---	---
S-91-4	---	---	---	---	---	---	---	---	---
S-93-2S	---	---	---	---	---	---	---	---	---
S-93-2D	---	---	---	---	---	---	---	---	---
S-93-5S	---	---	---	---	---	---	---	---	---
S-93-5D	---	---	---	---	---	---	---	---	---
S-93-7	---	---	---	---	---	---	---	---	---
S-95-1	---	---	---	---	---	---	---	---	---
*SP-11 / SP-10	---	---	---	---	---	---	---	---	---
TW-1	---	---	---	---	---	---	---	---	---
TW-2	---	---	---	---	---	---	---	---	---
Swamp Pond	---	---	---	---	---	---	---	---	---

--- = Not sampled.

* = S-5 replaced by S-5R during Summer 1993, SP-10 replaced SP-11 during Fall 1996, and S-3R replaced S-3 during Fall 1999.

Target Cleanup Level = 40 ug/L. Exceedences are bolded.

Table E-1 (continued)
Total PAH Concentrations (ug/L)
Historical Data (1984-2000)
BNSF Tie Plant - Somers, MT

Well Number	March 1988	June 1988	July 1988	Aug 1988	Sept 1988	Dec 1988	March 1989	June 1989	Sept 1989	Dec 1989
S-1	---	---	---	---	---	---	---	---	---	---
S-2	---	---	---	---	---	---	---	---	---	---
*S-3 / S-3R	<3	<1	---	---	<1	<1	<1	<1	<1	<1
S-4	<2	<1	---	---	<1	<1	<1	<1	<1	<1
*S-5 / S-5R	<2	<1	---	---	<1	<1	<1	<1	<1	<1
S-6	---	---	---	---	---	---	---	---	---	---
S-8	---	---	---	---	---	---	---	---	---	---
S-84-1	---	---	---	---	---	---	---	---	---	---
S-84-3	---	---	---	---	---	---	---	---	---	---
S-84-4	---	---	---	---	---	---	---	---	---	---
S-84-5	---	---	---	---	---	---	---	---	---	---
S-84-6	---	---	---	---	---	---	---	---	---	---
S-84-9	---	---	---	---	---	---	---	---	---	---
S-84-10	---	---	---	---	---	---	---	---	---	---
S-84-11	1,200	1,100	---	---	830	390	47	<1	4	3
S-84-14	414,400	---	---	---	---	---	---	---	---	---
S-84-15	---	---	---	---	---	---	---	---	---	---
S-84-16	---	---	---	---	---	---	---	---	---	---
S-85-1b	---	---	---	---	---	---	---	---	---	---
S-85-2	---	---	---	---	---	---	---	---	---	---
S-85-3	<2	<2	---	---	<1	<1	<1	<1	<1	<1
S-85-4a	<2	---	---	---	---	---	---	---	---	---
S-85-4b	<2	---	---	---	---	---	---	---	---	---
S-85-4c	<2	---	---	---	---	---	---	---	---	---
S-85-5a	<2	---	---	---	---	---	---	---	---	---
S-85-5b	<2	---	---	---	---	---	---	---	---	---
S-85-6a	---	<1	---	---	---	---	---	---	---	---
S-85-6b	---	---	---	---	---	---	---	---	---	---
S-85-7	<2	<1	<2	<2	---	---	---	---	---	---
S-85-8a	---	---	<2	<2	---	---	---	---	---	---
S-85-8b	---	---	<2	<2	---	---	---	---	---	---
S-86-1	<2	<1	---	---	<1	<1	<1	<1	<1	<1
S-88-1	---	559	256	1,795	---	---	---	---	---	---
S-88-2	---	2,123	503	3,779	---	---	---	---	---	---
S-88-3	---	150	130	67	---	---	---	---	---	---
S-91-1	---	---	---	---	---	---	---	---	---	---
S-91-3	---	---	---	---	---	---	---	---	---	---
S-91-4	---	---	---	---	---	---	---	---	---	---
S-93-2S	---	---	---	---	---	---	---	---	---	---
S-93-2D	---	---	---	---	---	---	---	---	---	---
S-93-5S	---	---	---	---	---	---	---	---	---	---
S-93-5D	---	---	---	---	---	---	---	---	---	---
S-93-7	---	---	---	---	---	---	---	---	---	---
S-95-1	---	---	---	---	---	---	---	---	---	---
*SP-11 / SP-10	---	---	---	---	---	---	---	---	---	---
TW-1	---	---	---	---	---	---	---	---	---	---
TW-2	---	---	---	---	---	---	---	---	---	---
Swamp Pond	---	---	---	---	---	---	---	---	---	---

--- = Not sampled.

* = S-5 replaced by S-5R during Summer 1993, SP-10 replaced SP-11 during Fall 1996, and S-3R replaced S-3 during Fall 1999.

Target Cleanup Level = 40 ug/L. Exceedences are bolded.

--- = Not sampled.

* = S-5 replaced by S-5R during Summer 1993, SP-10 replaced SP-11 during Fall 1996, and S-3R replaced S-3 during Fall 1999.

Target Cleanup Level = 40 ug/L. Exceedences are bolded.

Table E-1 (continued)
Total PAH Concentrations (ug/L)
Historical Data (1984-2000)
BNSF Tie Plant - Somers, MT

Well Number	March 1990	Sept 1990	March 1991	Sept 1991	March 1992	Sept 1992	March 1993	Sept 1993
S-1	---	---	---	---	---	---	---	---
S-2	---	---	---	---	---	---	---	---
*S-3 / S-3R	<1	<1	<1	<1	<1	<1	<1	<1
S-4	<1	582	<1	<1	<1	<1	<1	<1
*S-5 / S-5R	---	<1	<1	<1	<1	<1	<1	<1
S-6	---	---	---	---	---	---	---	<1
S-8	---	---	---	---	---	---	---	---
S-84-1	---	---	---	---	---	---	---	---
S-84-3	---	---	---	---	---	---	---	---
S-84-4	---	---	---	---	---	---	---	---
S-84-5	---	---	---	---	---	---	---	---
S-84-6	---	---	---	---	---	---	---	---
S-84-9	---	---	---	---	---	---	---	---
S-84-10	---	---	---	---	---	---	---	---
S-84-11	<1	<1	<1	<1	<1	<1	<1	<1
S-84-14	---	---	---	---	---	---	---	---
S-84-15	---	---	---	---	---	---	---	---
S-84-16	---	---	---	---	---	---	---	---
S-85-1b	---	<1	---	---	---	---	---	---
S-85-2	---	---	---	---	---	---	---	---
S-85-3	<1	<1	<1	<1	<1	<1	<1	<1
S-85-4a	---	---	---	---	---	---	---	---
S-85-4b	---	---	---	---	---	---	---	---
S-85-4c	---	---	---	---	---	---	---	---
S-85-5a	---	---	---	---	---	---	---	<1
S-85-5b	---	---	---	---	---	---	---	---
S-85-6a	---	---	---	---	---	---	---	---
S-85-6b	---	---	---	---	---	---	---	---
S-85-7	---	<1	---	---	<1	<1	<1	---
S-85-8a	---	<1	---	---	---	---	---	<1
S-85-8b	---	<1	---	---	<1	<1	---	---
S-86-1	<1	<1	<1	<1	<1	<1	<1	<1
S-88-1	---	---	---	---	---	---	---	---
S-88-2	---	---	---	---	---	---	---	---
S-88-3	---	<1	---	---	---	---	---	---
S-91-1	---	---	---	---	<1	<1	<1	<1
S-91-3	---	---	---	---	<1	<1	<1	<1
S-91-4	---	---	---	---	<1	<1	<1	<1
S-93-2S	---	---	---	---	---	---	---	---
S-93-2D	---	---	---	---	---	---	---	---
S-93-5S	---	---	---	---	---	---	---	---
S-93-5D	---	---	---	---	---	---	---	---
S-93-7	---	---	---	---	---	---	---	<1
S-95-1	---	---	---	---	---	---	---	---
*SP-11 / SP-10	---	---	---	---	---	---	---	15
TW-1	---	---	---	---	---	---	---	---
TW-2	---	---	---	---	---	---	---	---
Swamp Pond	---	---	---	---	---	---	---	---

mpled.
 aced by S-5R during Summer 1993, SP-10 replaced SP-11 during Fall 1996,
 iR replaced S-3 during Fall 1999.
 inup Level = 40 ug/L. Exceedences are bolded.

Table E-1 (continued)
Total PAH Concentrations (ug/L)
Historical Data (1984-2000)
BNSF Tie Plant - Somers, MT

Well Number	March 1994	August 1994	Nov 1994	March 1995	May 1995	Sept 1995	Dec 1995
S-1	---	---	---	---	---	---	---
S-2	---	---	---	---	---	---	---
*S-3 / S-3R	<1	<1	---	<1	---	<1	---
S-4	<1	<1	---	<1	---	<1	---
*S-5 / S-5R	<1	<1	---	<1	---	<1	---
S-6	<1	<1	---	<1	---	<1	---
S-8	---	---	---	---	---	---	---
S-84-1	---	---	---	---	---	---	---
S-84-3	---	---	---	---	---	---	---
S-84-4	---	---	---	---	---	---	---
S-84-5	---	---	---	---	---	---	---
S-84-6	---	---	---	---	---	---	---
S-84-9	---	---	---	---	---	---	---
S-84-10	<1	<1	---	<1	---	<1	---
S-84-11	<1	<1	---	<1	---	<1	---
S-84-14	---	---	---	---	---	---	---
S-84-15	---	---	---	---	---	---	---
S-84-16	---	---	---	---	---	---	---
S-85-1b	---	---	---	---	---	---	---
S-85-2	---	---	---	---	---	---	---
S-85-3	<1	<1	---	<1	---	<1	---
S-85-4a	---	---	---	---	---	---	---
S-85-4b	---	---	---	---	---	---	---
S-85-4c	---	---	---	---	---	---	---
S-85-5a	<1	<1	---	<1	---	<1	---
S-85-5b	---	---	---	---	---	---	---
S-85-6a	---	---	---	---	---	---	---
S-85-6b	---	---	---	---	---	---	---
S-85-7	<1	<1	---	<1	---	<1	---
S-85-8a	<1	1	---	<1	---	<1	---
S-85-8b	<1	<1	---	<1	---	<1	---
S-86-1	<1	<1	---	---	---	---	---
S-88-1	---	---	---	---	---	---	---
S-88-2	---	---	---	---	---	---	---
S-88-3	---	---	---	---	---	---	---
S-91-1	<1	<1	---	<1	---	<1	---
S-91-3	<1	<1	---	<1	---	<1	---
S-91-4	<1	<1	---	<1	---	<1	---
S-93-2S	---	3,915	1,568	9,786	901	1,085	1,079
S-93-2D	---	2	2	1,300	33	5	4
S-93-5S	---	---	---	---	---	---	---
S-93-5D	---	533	305	50	87	129	---
S-93-7	<1	<1	---	<1	---	1	---
S-95-1	---	---	---	<1	---	<1	---
*SP-11 / SP-10	9	6	---	<1	---	641	---
TW-1	0.012	0.017	---	0.027	---	<0.010	---
TW-2	0.014	0.018	---	<0.010	---	<0.010	---
Swamp Pond	<1	<1	---	<1	---	<1	---

--- = Not sampled.

* = S-5 replaced by S-5R during Summer 1993, SP-10 replaced SP-11 during Fall 1996, and S-3R replaced S-3 during Fall 1999.

Target Cleanup Level = 40 ug/L. Exceedences are bolded.

Table E-1 (continued)
Total PAH Concentrations (ug/L)
Historical Data (1984-2000)
BNSF Tie Plant - Somers, MT

Well Number	April 1996	June 1996	Aug 1996	Dec 1996	May 1997	June 1997	Sept 1997	Dec 1997
S-1	---	---	---	---	---	---	---	---
S-2	---	---	---	---	---	---	---	---
*S-3 / S-3R	<1	---	<1	---	<1	---	<1	---
S-4	<1	---	<1	---	<1	---	<1	---
*S-5 / S-5R	<1	---	<1	---	<1	---	<1	---
S-6	<1	---	<1	---	<1	---	<1	---
S-8	---	---	---	---	---	---	---	---
S-84-1	---	---	---	---	---	---	---	---
S-84-3	---	---	---	---	---	---	---	---
S-84-4	---	---	---	---	---	---	---	---
S-84-5	---	---	---	---	---	---	---	---
S-84-6	---	---	---	---	---	---	---	---
S-84-9	---	---	---	---	---	---	---	---
S-84-10	<1	---	<1	---	<1	---	<1	---
S-84-11	<1	---	<1	---	<1	---	<1	---
S-84-14	---	---	---	---	---	---	---	---
S-84-15	---	---	---	---	---	---	---	---
S-84-16	---	---	---	---	---	---	---	---
S-85-1b	---	---	---	---	---	---	---	---
S-85-2	---	---	---	---	---	---	---	---
S-85-3	<1	---	<1	---	<1	---	<1	---
S-85-4a	---	---	---	---	---	---	---	---
S-85-4b	---	---	---	---	---	---	---	---
S-85-4c	---	---	---	---	---	---	---	---
S-85-5a	<1	---	1.3	---	<1	---	<1	---
S-85-5b	---	---	---	---	---	---	---	---
S-85-6a	---	---	<1	---	---	---	---	---
S-85-6b	---	---	2	---	---	---	---	---
S-85-7	<1	---	<1	---	<1	---	<1	---
S-85-8a	<1	---	<1	---	<1	---	<1	---
S-85-8b	<1	---	<1	---	<1	---	<1	---
S-86-1	---	---	---	---	---	---	---	---
S-88-1	---	---	900	---	---	---	---	---
S-88-2	---	---	1,377	---	431	---	465	---
S-88-3	---	---	400	---	380	---	350	---
S-91-1	4.6	---	<1	---	<1	---	<1	---
S-91-3	<1	---	<1	---	<1	---	<1	---
S-91-4	<1	---	<1	---	<1	---	<1	---
S-93-2S	1,044	5,367	868	1,539	401	911	2,561	609
S-93-2D	2	1	191	35	13	<1	8	32
S-93-5S	---	---	---	---	---	---	---	---
S-93-5D	---	---	---	---	---	---	---	---
S-93-7	<1	---	<1	---	<1	---	<1	---
S-95-1	<1	---	<1	---	<1	---	<1	---
*SP-11 / SP-10	243	---	<1	---	<1	---	<1	---
TW-1	0.012	---	---	---	<1	---	<1	---
TW-2	<1	---	---	---	<1	---	<1	---
Swamp Pond	<1	---	<1	---	<1	---	<1	---

--- = Not sampled.

* = S-5 replaced by S-5R during Summer 1993, SP-10 replaced SP-11 during Fall 1996, and S-3R replaced S-3 during Fall 1999.

Target Cleanup Level = 40 ug/L. Exceedences are bolded.

Table E-1 (continued)
Total PAH Concentrations (ug/L)
Historical Data (1984-2000)
BNSF Tie Plant - Somers, MT

Well Number	March 1998	June 1998	Sept 1998	Dec 1998	Mar 1999	June 1999	Sept 1999	Dec 1999	March 2000
S-1	---	---	---	---	---	---	---	---	---
S-2	---	---	---	---	---	---	---	---	---
*S-3 / S-3R	<1	---	<1	---	<1	---	0.11	---	<1
S-4	<1	---	<1	---	<1	---	<1	---	<1
*S-5 / S-5R	<1	---	<1	---	<1	---	<1	---	<1
S-6	3	---	570*	480	360	320	600	460	530
S-8	---	---	---	---	---	---	---	---	---
S-84-1	---	---	---	---	---	---	---	---	---
S-84-3	---	---	---	---	---	---	---	---	---
S-84-4	---	---	---	---	---	---	---	---	---
S-84-5	---	---	---	---	---	---	---	---	---
S-84-6	---	---	---	---	---	---	---	---	---
S-84-9	---	---	---	---	---	---	---	---	---
S-84-10	2	---	<1	---	<1	---	<1	---	<1
S-84-11	<1	---	<1	---	<1	---	<1	---	<1
S-84-14	---	---	---	---	---	---	---	---	---
S-84-15	---	---	<1	<1	<1	<1	<1	<1	<1
S-84-16	---	---	<1	<1	<1	<1	<1	<1	<1
S-85-1b	---	---	---	---	---	---	---	---	---
S-85-2	---	---	---	---	---	---	---	---	---
S-85-3	<1	---	<1	---	6	---	<1	---	<1/<1
S-85-4a	---	---	---	---	---	---	---	---	---
S-85-4b	---	---	---	---	---	---	---	---	---
S-85-4c	---	---	---	---	---	---	---	---	---
S-85-5a	<1	---	2	<1	7	<1	<1	<1	<1
S-85-5b	---	---	<1	<1	<1	<1	<1	<1	<1
S-85-6a	---	---	<1	<1	<1	<1	<1	<1	<1
S-85-6b	---	---	<1	<1	<1	<1	<1	<1	<1/<1
S-85-7	<1	---	<1	---	<1	---	<1	---	<1
S-85-8a	<1	---	<1	---	<1	---	<1	---	<1
S-85-8b	<1	---	<1	---	<1	---	<1	---	<1/1.2
S-86-1	---	---	---	---	---	---	---	---	---
S-88-1	12,828	---	6,907	---	8,613	---	12,381	11,339	6,901
S-88-2	1,361	---	478	698	331	159	881	720	59
S-88-3	490	---	360	310	140	100	<1	40	54
S-91-1	<1	---	<1	---	<1	---	<1	---	<1
S-91-3	<1	---	<1	---	<1	---	<1	---	<1
S-91-4	<1	---	<1	---	<1	---	<1	---	<1/<1
S-93-2S	1,155	1,267	2,000	416	2,912	4,058	1,922	1,397	2,387
S-93-2D	14	24	392	21	503	2,712	101	65	42
S-93-5S	---	---	---	---	---	---	---	---	---
S-93-5D	---	---	---	---	---	---	---	---	---
S-93-7	<1	---	<1	---	<1	---	<1	---	<1/<1
S-95-1	<1	---	<1	---	<1	---	<1	---	<1
*SP-11 / SP-10	<1	---	<1	---	<1	---	<1	---	<1
TW-1	<1	---	<1	---	<1	---	<1	---	<1
TW-2	<1	---	<1	---	<1	---	<1	---	<1
Swamp Pond	<1	---	<1	---	<1	---	<1	---	<1

* S-6 Resample collected in October 1998 was 430 ug/L

--- = Not sampled.

* = S-5 replaced by S-5R during Summer 1993, SP-10 replaced SP-11 during Fall 1996, and S-3R replaced S-3 during Fall 1999.

Target Cleanup Level = 40 ug/L. Exceedences are bolded.

Table E-2
Summary Analytical Results - Well S-6
BNSF - Somers, MT

Sample Location: Collection Date:	S-6 03/05/98	S-6 09/02/98	S-6 10/12/98	S-6 11/30/98	S-6 03/01/99	S-6 04/13/99	S-6 06/01/99	S-6 09/01/99	S-6 12/01/99	S-6 03/01/00
Semivolatile Method 8270 (ug/L)										
Phenol	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	2.7
Bis-(2-Chloroethyl) Ether	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0
2-Chlorophenol	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
1,3-Dichlorobenzene	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
1,4-Dichlorobenzene	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Benzyl Alcohol	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0
1,2-Dichlorobenzene	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
2-Methylphenol	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	U 1.2	< 2.0	< 2.0
2,2'-Oxybis(1-Chloropropane)	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
4-Methylphenol	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
N-Nitroso-Di-N-Propylamine	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0
Hexachloroethane	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0
Nitrobenzene	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Isophorone	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
2-Nitrophenol	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0
2,4-Dimethylphenol	< 3.0	< 3.0	< 3.0	< 3.0	< 3.0	< 3.0	3.2	13	6.4	< 3.0
Benzoic Acid	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
bis(2-Chloroethoxy) Methane	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
2,4-Dichlorophenol	< 3.0	< 3.0	< 3.0	< 3.0	< 3.0	< 3.0	< 3.0	< 3.0	< 3.0	< 3.0
1,2,4-Trichlorobenzene	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Naphthalene	3.3	D 570	D 430	D 480	D 360	D 250	D 320	D 600	D 460	D 530
4-Chloroaniline	< 3.0	< 3.0	< 3.0	< 3.0	< 3.0	< 3.0	< 3.0	< 3.0	< 3.0	< 3.0
Hexachlorobutadiene	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0
4-Chloro-3-methylphenol	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0
2-Methylnaphthalene	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	UJ 0.5	< 1.0	< 1.0
Hexachlorocyclopentadiene	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0
2,4,6-Trichlorophenol	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0
2,4,5-Trichlorophenol	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0
2-Chloronaphthalene	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
2-Nitroaniline	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0
Dimethylphthalate	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Acenaphthylene	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
3-Nitroaniline	< 6.0	< 6.0	< 6.0	< 6.0	< 6.0	< 6.0	< 6.0	< 6.0	< 6.0	< 6.0
Acenaphthene	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
2,4-Dinitrophenol	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
4-Nitrophenol	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0
Dibenzofuran	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
2,6-Dinitrotoluene	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0
2,4-Dinitrotoluene	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0
Diethylphthalate	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
4-Chlorophenyl-phenylether	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Fluorene	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
N-Nitrosodiphenylamine	< 1.0	< 1.0	< 1.0	< 5.0	< 1.0	< 1.0	< 5.0	< 1.0	< 1.0	< 1.0
4-Nitroaniline	< 5.0	< 5.0	< 5.0	< 10	< 5.0	< 5.0	< 10	< 5.0	< 5.0	< 5.0
4,6-Dinitro-2-Methylphenol	< 10	< 10	< 10	< 1.0	< 10	< 10	< 1.0	< 10	< 10	< 10
4-Bromophenyl-phenylether	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Hexachlorobenzene	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Pentachlorophenol	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0
Phenanthrene	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Carbazole	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0

Table E-2
Summary Analytical Results - Well S-6
BNSF - Somers, MT

Sample Location: Collection Date:	S-6 03/05/98	S-6 09/02/98	S-6 10/12/98	S-6 11/30/98	S-6 03/01/99	S-6 04/13/99	S-6 06/01/99	S-6 09/01/99	S-6 12/01/99	S-6 03/01/00
Anthracene	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Di-n-Butylphthalate	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Fluoranthene	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Pyrene	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Butylbenzylphthalate	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
3,3'-Dichlorobenzidine	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0
Benzo(a)anthracene	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
bis(2-Ethylhexyl)phthalate	< 1.0	< 1.0	2.2	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Chrysene	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Di-n-Octyl phthalate	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Benzo(b)fluoranthene	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Benzo(k)fluoranthene	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Benzo(a)pyrene	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Indeno(1,2,3-cd)pyrene	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Dibenzo(a,h)anthracene	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Benzo(g,h,i)perylene	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Total PAH (ug/L)	3.3	570	430	480	360	250	320	600	460	530
Total Phenols (ug/L)	0	0	0	0	0	0	3.2	14.2	6.4	2.7
Total Suspended Solids (mg/L)	1.7	63	5.1	29	180	44	20	42	14	8.9
Zinc (mg/L)	0.127	5.90	0.283	0.735	0.008	0.496	0.419	0.0451	0.553	0.914

D= Diluted sample.

U = Non-detect due to field blank contamination - determined during data validation.

UJ = Estimated non-detect due to possible matrix effects (RPD out of limits) - determined during data validation.

Target cleanup levels: TPAH = 40 µg/L, phenols = 6,000 µg/L, Zinc = 5 mg/L. Exceedences are bolded.

Table E-3
Groundwater Analytical Results - Well S-91-2
April 2000
BNSF - Somers, MT

Sample Location: Collection Date:	S-91-2 04/17/00	Method Blank
Semivolatile Method 8270 (ug/L)		
Phenol	< 2.0	< 2.0
Bis-(2-Chloroethyl) Ether	< 2.0	< 2.0
2-Chlorophenol	< 1.0	< 1.0
1,3-Dichlorobenzene	< 1.0	< 1.0
1,4-Dichlorobenzene	UJ <1.0	< 1.0
Benzyl Alcohol	< 5.0	< 5.0
1,2-Dichlorobenzene	< 1.0	< 1.0
2-Methylphenol	4.0	< 2.0
2,2'-Oxybis(1-Chloropropane)	< 1.0	< 1.0
4-Methylphenol	3.4	< 1.0
N-Nitroso-Di-N-Propylamine	UJ <2.0	< 2.0
Hexachloroethane	< 2.0	< 2.0
Nitrobenzene	< 1.0	< 1.0
Isophorone	< 1.0	< 1.0
2-Nitrophenol	< 5.0	< 5.0
2,4-Dimethylphenol	D 3,800	< 3.0
Benzoic Acid	< 10	< 10
bis(2-Chloroethoxy) Methane	< 1.0	< 1.0
2,4-Dichlorophenol	< 3.0	< 3.0
1,2,4-Trichlorobenzene	UJ <1.0	< 1.0
Naphthalene	3.3	< 1.0
4-Chloroaniline	< 3.0	< 3.0
Hexachlorobutadiene	< 2.0	< 2.0
4-Chloro-3-methylphenol	< 2.0	< 2.0
2-Methylnaphthalene	1.4	< 1.0
Hexachlorocyclopentadiene	< 5.0	< 5.0
2,4,6-Trichlorophenol	< 5.0	< 5.0
2,4,5-Trichlorophenol	< 5.0	< 5.0
2-Chloronaphthalene	< 1.0	< 1.0
2-Nitroaniline	< 5.0	< 5.0
Dimethylphthalate	< 1.0	< 1.0
Acenaphthylene	< 1.0	< 1.0
3-Nitroaniline	< 6.0	< 6.0
Acenaphthene	UJ <1.0	< 1.0
2,4-Dinitrophenol	< 10	< 10
4-Nitrophenol	< 5.0	< 5.0

Table E-3
Groundwater Analytical Results - Well S-91-2
April 2000
BNSF - Somers, MT

Sample Location: Collection Date:	S-91-2 04/17/00	Method Blank
Dibenzofuran	< 1.0	< 1.0
2,6-Dinitrotoluene	< 5.0	< 5.0
2,4-Dinitrotoluene	UJ <1.0	< 5.0
Diethylphthalate	< 1.0	< 1.0
4-Chlorophenyl-phenylether	< 1.0	< 1.0
Fluorene	< 1.0	< 1.0
N-Nitrosodiphenylamine	< 1.0	< 1.0
4-Nitroaniline	< 5.0	< 5.0
4,6-Dinitro-2-Methylphenol	< 10	< 10
4-Bromophenyl-phenylether	< 1.0	< 1.0
Hexachlorobenzene	< 1.0	< 1.0
Pentachlorophenol	< 5.0	< 5.0
Phenanthrene	< 1.0	< 1.0
Carbazole	< 1.0	< 1.0
Anthracene	< 1.0	< 1.0
Di-n-Butylphthalate	< 1.0	< 1.0
Fluoranthene	< 1.0	< 1.0
Pyrene	UJ <1.0	< 1.0
Butylbenzylphthalate	< 1.0	< 1.0
3,3'-Dichlorobenzidine	< 5.0	< 5.0
Benzo(a)anthracene	< 1.0	< 1.0
bis(2-Ethylhexyl)phthalate	< 1.0	< 1.0
Chrysene	< 1.0	< 1.0
Di-n-Octyl phthalate	< 1.0	< 1.0
Benzo(b)fluoranthene	< 1.0	< 1.0
Benzo(k)fluoranthene	< 1.0	< 1.0
Benzo(a)pyrene	< 1.0	< 1.0
Indeno(1,2,3-cd)pyrene	< 1.0	< 1.0
Dibenzo(a,h)anthracene	< 1.0	< 1.0
Benzo(g,h,i)perylene	< 1.0	< 1.0
Total PAH (ug/L)	3.3	0
Total Phenols (ug/L)	3,807	0
Total Suspended Solids 160.2 (mg/L)	130	< 1.0

D = Diluted sample.

UJ = Non-detect, reporting limit estimated due to LCS recovery, determined during data validation.

Target cleanup levels:TPAH=40 µg/L, phenols=6,000 µg/L, Zinc=5 mg/L. Exceedences are bolded.